COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

GEOLOGY OF THE HYLAS AND MIDLOTHIAN QUADRANGLES, VIRGINIA

BRUCE K. GOODWIN

REPORT OF INVESTIGATIONS 23

VIRGINIA DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
1970

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

GEOLOGY OF THE HYLAS AND MIDLOTHIAN QUADRANGLES, VIRGINIA

BRUCE K. GOODWIN

REPORT OF INVESTIGATIONS 23

VIRGINIA DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
1970

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF PURCHASES AND SUPPLY
RICHMOND
1970

DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

Richmond, Virginia

MARVIN M. SUTHERLAND, *Director*
CHARLES A. CHRISTOPHERSEN, *Deputy Director*
A. S. RACHAL, JR., *Executive Assistant*

CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY OF THE HYLAS AND MIDLOTHIAN QUADRANGLES, VIRGINIA

By

BRUCE K. GOODWIN[1]

ABSTRACT

The Hylas and Midlothian 7.5-minute quadrangles are located in the eastern Virginia Piedmont about 9 miles west of Richmond. Igneous, metamorphic, and sedimentary rocks are present. Igneous rocks include the Petersburg granite and the associated quartz monzonite porphyry, pegmatites, and diabase dikes. Granite gneiss, biotite gneiss, amphibolite, and metavolcanic rocks are the dominant metamorphic lithologies. Triassic sedimentary rocks in the Richmond basin consist of arkosic sandstone, shale, coarse conglomerate, and coal. Coarse gravels of probable Tertiary age mantle the upland surfaces of the Midlothian quadrangle.

The granite gneiss, biotite gneiss, and amphibolite, which are Precambrian(?) in age, have been deformed into overturned, nearly isoclinal folds. These rocks have pronounced foliation and lineations are generally well developed.

Metavolcanic rocks, which are at a lower metamorphic grade, overlie the older gneisses in angular unconformity. They are phyllitic to gneissic in texture and have also been deformed into nearly isoclinal folds. The Petersburg granite of probable late Paleozoic age is intrusive into the metavolcanic rocks.

Sedimentary rocks of Triassic age along the eastern edge of the Richmond basin are nonconformable upon the Petersburg granite. A pronounced normal fault that is offset along later normal faults forms the western boundary of the basin. Sediments were supplied to the basin from both easterly and westerly sources. Tertiary gravels lie in angular unconformity upon the eroded Triassic rocks. One of these gravels covers the upland surfaces in the Midlothian quadrangle and contains highly weathered pebbles and cobbles. Another Tertiary gravel unit occurs at lower elevations and contains fresher pebbles and cobbles.

Large quantities of crushed stone are presently being produced from igneous and metamorphic rocks within the quadrangles. In former years, coal deposits of Triassic age were actively

[1] Department of Geology, College of William and Mary, Williamsburg, Virginia.

mined. Several prospects for rutile have been made in the northwestern part of the area.

INTRODUCTION

The Hylas (Plate 1) and Midlothian (Plate 2) 7.5-minute quadrangles are located in east-central Virginia 9 miles west of Richmond (Figure 1). They encompass a combined area of 118 square miles bounded by parallels 37°30′ and 37°45′ north latitude and meridians 77°37′30″ and 77°45′ west longitude. The area of study includes portions of Goochland, Hanover, Powhatan, Chesterfield, and Henrico counties. Midlothian is the largest town in the area. Small communities occur at Hylas, Johnsons Springs, Rockville, Centerville, Manakin, and Sabot.

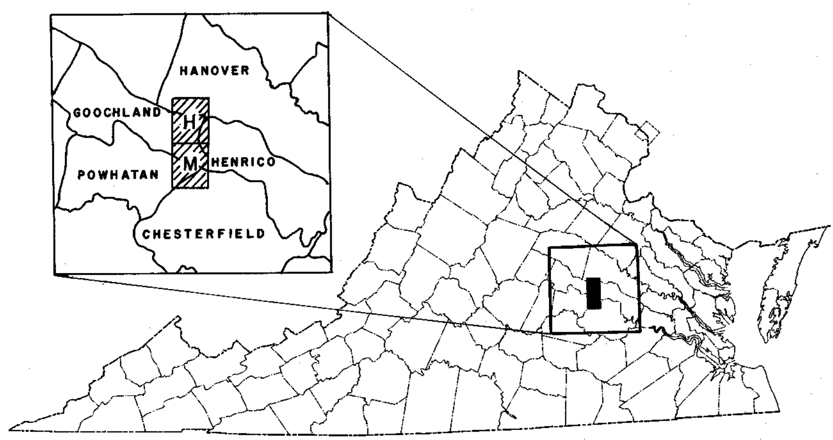


Figure 1. Index map showing location of Hylas and Midlothian quadrangles.

Four major highways, Interstate Highway 64, U. S. Highway 250, U. S. Highway 60, and State Highway 6, traverse the area from east to west, and several State Roads also are present. The Chesapeake and Ohio Railway traverses the area on the north side of the James River, and the Southern Railway crosses the southeast corner of the area immediately north of Midlothian.

The field work for this report was done primarily during the summers of 1964, 1965, and 1968 with occasional days spent in the field during the intervening winters and summers. The Virginia Division of Mineral Resources financed the field work and a drilling program in the summer of 1969 that resulted in 35 test holes. The drilling was by auger boring, and split-spoon samples were taken at 5-foot intervals. The writer accompanied the drillers in order to record more accurately the nature of the units penetrated. Numbers preceded by "W" in parentheses (W-2397) correspond to well localities on Plates 1 and 2. Summaries of these wells are given in Appendix I.

The author wishes to acknowledge the encouragement and support of Dr. James L. Calver, Commissioner of Mineral Resources and State Geologist. Gerald H. Johnson provided valuable insight into some of the problems during discussions and field trips in the area. Stephen C. Clement read portions of the manuscript and offered many helpful suggestions. Stephen B. Goodwin served as a faithful field assistant. Harold L. Mathews and Thomas R. Burruss, soil scientists with the Soil Conservation Service, United States Department of Agriculture, were of invaluable aid in studying those portions of Chesterfield and Goochland counties which lie within the mapped area. Thanks are also given to the many residents of the area for their courtesy and aid.

The Hylas and Midlothian 7.5-minute quadrangles lie within the Piedmont physiographic province. A portion of the Triassic lowland subprovince is represented here by the northern end of the Richmond basin, occupying much of the Midlothian quadrangle and terminating in the southeastern quarter of the Hylas quadrangle. Low, gently rolling terrain characterizes the area and presents a mature topography. Deep weathering has produced a thick residual soil that obscures the bedrock. Total relief is greatest south of the James River. The maximum and minimum elevations and total relief for three areas within the quadrangles are as follows:

Area	Maximum Elevation in Feet	Minimum Elevation in Feet	Total Relief in Feet
Hylas quadrangle	380+	140	240+
Midlothian quadrangle (North of James River)	310+	117	193+
Midlothian quadrangle (South of James River)	420+	117	303+

The dominant use of land within the area is for agricultural purposes although an increasing number of residential dwellings are appearing as the population of metropolitan Richmond expands and rural areas become more desirable as homesites. Both beef and dairy cattle are raised in the area, and most of the crops are for the support of cattle production. Large areas of woodland have furnished timber in the past and some logging operations are still being conducted.

The James River is the major watercourse in the area; it drains the southern two-thirds of the Hylas quadrangle and most of the Midlothian quadrangle. The larger streams entering the James River from the north are Tuckahoe Creek, with its extensive tributary system, and Dover Creek. Norwood Creek, Bernards Creek, and several minor streams enter the James River from the south. The northern one-sixth of the area is traversed by several small streams such as Mill Creek and Goldmine Creek which flow northward and northeastward to the South Anna River. The headwaters of Falling Creek drain the southeastern corner of the area, and most of the extreme southern portion is drained by small tributaries of Swift Creek. Most of the larger streams flowing over areas underlain by metamorphic rocks have north-northeastward trending courses, following the major trend of underlying rock structures. Tuckahoe Creek has developed on the less resistant rocks of the Triassic lowland and thus was able to extend its valley and tributaries more successfully than the streams traversing gneissic bedrock. The main course of this stream trends west of north, and its major tributaries extend generally northward.

Although geologic work in the area of this report has been conducted sporadically since the middle 1800's, little work of a detailed nature has been carried out. The most notable exception is the Richmond basin of Triassic age which received much attention by early writers due to the presence of coal deposits; these coals were the first to be mined in the United States.

One of the earliest works on the Triassic rocks was by Sir Charles Lyell (1847). Since then, much has been written about the coals, fossils, stratigraphy, and structure of the Richmond basin. The major works dealing with this area are by Ashburner (1888), Shaler and Woodworth (1899), Woodworth (1902), and Roberts (1928). Shaler and Woodworth (1899) produced a geologic map of the Richmond basin which has required very little modification as the result of later investigations.

The Petersburg granite, underlying much of Richmond, Petersburg, and neighboring areas to the west, has provided quantities of crushed, dimension, and monumental stone. Consequently several reports have dealt with the characteristics of this granite where it has been quarried. The major publications about the Petersburg granite were by Watson (1906, 1910), Darton

(1911), Bloomer (1939), and Steidtmann (1945). Brown (1937) described the geology and mineral resources of Goochland County, and Bloomer (1938) studied the geology of Chesterfield County. Portions of these counties are within the mapped area.

STRATIGRAPHY

Seven major stratigraphic units are present within the area of this report. These are granite gneiss, biotite gneiss, amphibolite, metavolcanic rocks, the Petersburg granite, the Triassic sedimentary rocks of the Richmond basin, and gravels of probable Tertiary age. A few diabase dikes intrude the Triassic sedimentary rocks and the metavolcanic rocks. Pegmatites also intrude the Petersburg granite and the granite gneiss. The geologic units present in the Hylas and Midlothian quadrangles are summarized in Table 1.

The geologic age of the metavolcanic rocks and the gneisses is not known, and the age of the Petersburg granite is also uncertain. However, the relative ages of these units can be determined. The oldest units present are the granite gneiss, biotite gneiss, and amphibolite, which are considered to be Precambrian(?). The metavolcanic unit, which is considered to be Paleozoic, is thought to be younger than the gneisses and amphibolite because it overlies them as an angular unconformity (Plate 1). The Petersburg granite is intrusive into both the

Table 1.—Geologic units in the Hylas and Midlothian quadrangles.

AGE		LITHOLOGY	
Cenozoic	Quaternary	Alluvium	
	Tertiary	Gravel, sand, and clay Gravel, sand, and clay that are highly weathered and partially cemented	
Mesozoic	Triassic	Diabase dikes	
		Conglomerate	Sandstone and shale
			Shale
			Coal measures
Paleozoic		Petersburg granite, including quartz monzonite porphyry	
		Metavolcanic rocks	
Precambrian (?)		Amphibolite Biotite gneiss Granite gneiss	

gneisses and the metavolcanic rocks and was probably emplaced during late Paleozoic time. Sedimentary rocks of Triassic age include coal, shale, arkosic sandstone, and conglomerate. The diabase dikes are also considered to be of Triassic age. Two units composed of coarse gravels overlie the older rocks as discontinuous, highly dissected blankets. They are unfossiliferous and their age is, therefore, tenatively designated as Tertiary. Quaternary alluvium occurs on the floodplain of the James River and along some of the other streams in the area.

PRECAMBRIAN (?) ROCKS

Granite Gneiss and Biotite Gneiss

Granite gneiss (R-3088) and biotite gneiss (R-3089) underlie much of the northwestern quarter of the area. Although the two gneisses are commonly interlayered and the composition of each differs, two areas dominated by biotite-rich gneiss are delineated on Plate 1. The biotite gneiss (R-3087) is well exposed along the right bank of the South Anna River 0.1 mile west of where it is crossed by State Road 673. Granite gneiss dominates the remainder of the gneissic terrain; relatively uniform, even-banded, well-foliated granite gneiss (Figure 2) is present in large exposures along the tracks of the Chesapeake and Ohio

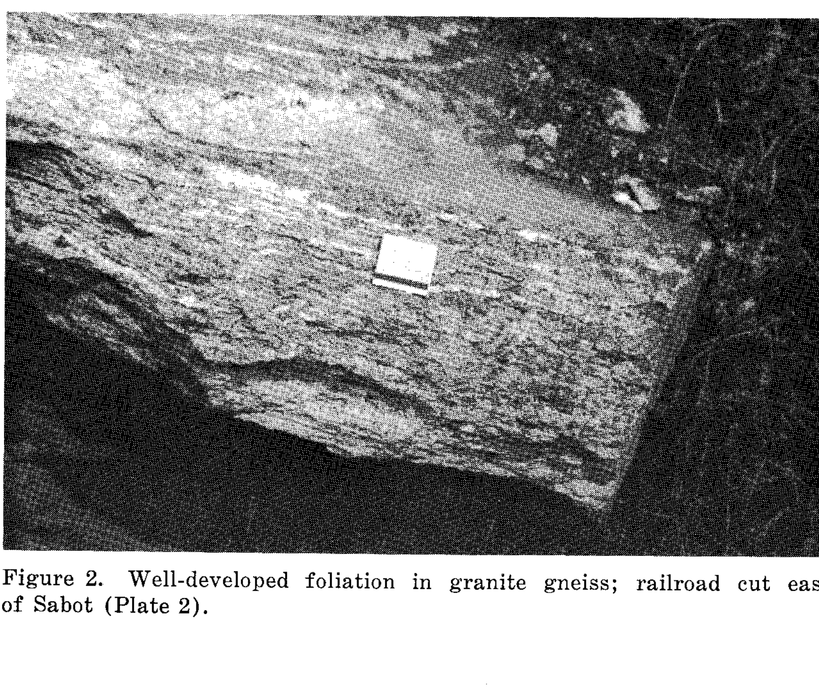


Figure 2. Well-developed foliation in granite gneiss; railroad cut east of Sabot (Plate 2).

gneisses and the metavolcanic rocks and was probably emplaced during late Paleozoic time. Sedimentary rocks of Triassic age include coal, shale, arkosic sandstone, and conglomerate. The diabase dikes are also considered to be of Triassic age. Two units composed of coarse gravels overlie the older rocks as discontinuous, highly dissected blankets. They are unfossiliferous and their age is, therefore, tenatively designated as Tertiary. Quaternary alluvium occurs on the floodplain of the James River and along some of the other streams in the area.

PRECAMBRIAN (?) ROCKS

Granite Gneiss and Biotite Gneiss

Granite gneiss (R-3088) and biotite gneiss (R-3089) underlie much of the northwestern quarter of the area. Although the two gneisses are commonly interlayered and the composition of each differs, two areas dominated by biotite-rich gneiss are delineated on Plate 1. The biotite gneiss (R-3087) is well exposed along the right bank of the South Anna River 0.1 mile west of where it is crossed by State Road 673. Granite gneiss dominates the remainder of the gneissic terrain; relatively uniform, even-banded, well-foliated granite gneiss (Figure 2) is present in large exposures along the tracks of the Chesapeake and Ohio

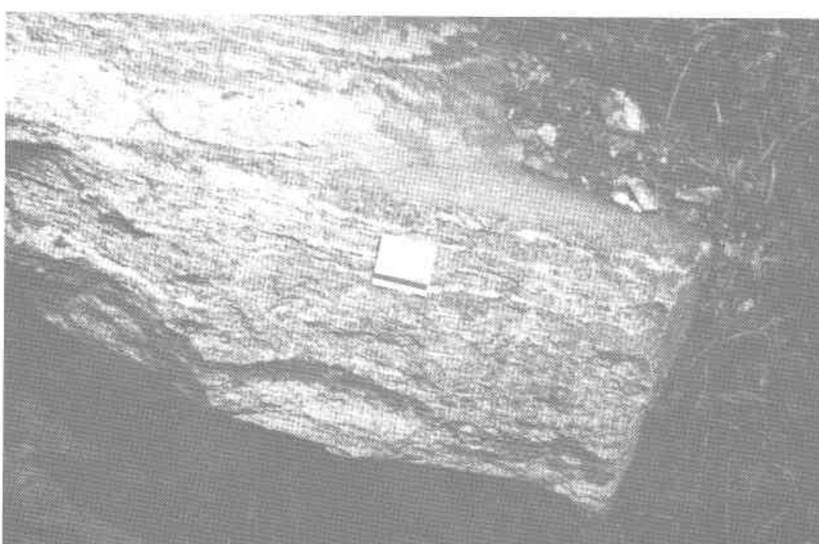


Figure 2. Well-developed foliation in granite gneiss; railroad cut east of Sabot (Plate 2).

Railway east of Sabot (Plate 2). Megascopically, the granite gneiss unit ranges from poorly foliated, light gray, and fine grained to an intensely foliated, medium- to coarse-grained biotite granite gneiss. The biotite gneiss is dark gray, fine to medium grained, biotite rich, and invariably intensely foliated, in places approaching a schistose texture.

Approximate mineral compositions are given for five samples of typical gneiss from the area of study (Appendix II). Quartz, potassic feldspar, plagioclase feldspar, and biotite occur in all specimens examined. Hornblende and garnet are also common constituents, while accessory minerals include apatite, sphene, and zircon. In thin section, the quartz commonly shows strain shadows and is anhedral, as are the plagioclase and orthoclase. The garnet is generally subhedral and highly fractured; some of the garnets appear to have been rotated during their growth. Biotite and hornblende tend to be oriented parallel to the foliation, and the gneissose texture is accentuated by laminae of quartz crystals which wrap around porphyroblasts of feldspar. In biotite-rich specimens, laminae dominated by biotite are also bent around feldspar porphyroblasts.

The granite gneiss was named the State Farm gneiss by Brown (1937) who mapped and described it as a Precambrian, biotite-oligoclase gneiss of igneous origin. Brown (1937, p. 14) considered the State Farm gneiss to be older than the aporhyolite (metavolcanic rocks of this report) and the Petersburg granite, a conclusion that is supported by the present study. Here the metavolcanic rocks are exposed above the gneiss in a syncline, and both gneiss and metavolcanic rocks have been intruded by the Petersburg granite.

The gneisses are jointed and in many places have well-developed foliation (Figure 3). On the foliation surfaces, lineations have been formed parallel to the regional *b* direction of folding. Lineations consist both of mineral parallelism and small crenulations. Cross-cutting veins of quartz, granite, and pegmatite have filled some of the joints. Thin laminae of quartz, granite, and pegmatite also occur parallel to the foliation. The majority of such veins are small, ranging in width from 0.5 inch to 5 inches. Quartz is the dominant vein material, and in many roadcuts where weathering has been intense the foliation of the gneiss is reflected by a series of thin quartz veins that have resisted decomposition.

Figure 3. Granite gneiss that is jointed and has well-developed foliation; railroad cut east of Sabot (Plate 2).

Pegmatites up to 3 feet wide occur within the gneiss. These large pegmatites are generally concordant although a few transect the foliation at a slight angle (Figure 4), and some are discordant. In the large exposures along the south bank of the South Anna River (Plate 1), there are discontinuous concordant pegmatite stringers 6 inches wide. These pegmatites are composed primarily of quartz and pink orthoclase with minor amounts of biotite. Associated with them are elliptical pods of pegmatite. The long axes of the pods are parallel to the strike of foliation. Some of these pods, which are enclosed by garnetiferous biotite gneiss, are nearly circular and have diameters up to 3 inches. In all of the pegmatites observed, the mineralogy was simple and no rare minerals were seen. Rutile has been reported by Watson and Taber (1913) from pegmatites exposed in old prospect pits north of U. S. Highway 250, northwest of Centerville.

Amphibolite

Interlayered with the granite gneiss are units of amphibolite (R-4081) that in some areas can be traced for considerable distances. The units mapped as amphibolite are variable in composition, with amphibolite and hornblende gneiss being dominant. The amphibolite is generally well foliated and ranges from fine

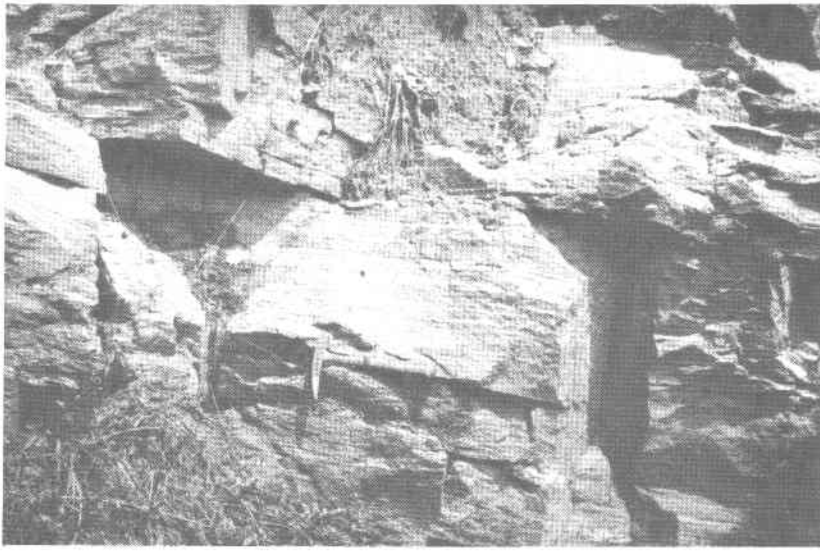


Figure 3. Granite gneiss that is jointed and has well-developed foliation; railroad cut east of Sabot (Plate 2).

Pegmatites up to 3 feet wide occur within the gneiss. These large pegmatites are generally concordant although a few transect the foliation at a slight angle (Figure 4), and some are discordant. In the large exposures along the south bank of the South Anna River (Plate 1), there are discontinuous concordant pegmatite stringers 6 inches wide. These pegmatites are composed primarily of quartz and pink orthoclase with minor amounts of biotite. Associated with them are elliptical pods of pegmatite. The long axes of the pods are parallel to the strike of foliation. Some of these pods, which are enclosed by garnetiferous biotite gneiss, are nearly circular and have diameters up to 3 inches. In all of the pegmatites observed, the mineralogy was simple and no rare minerals were seen. Rutile has been reported by Watson and Taber (1913) from pegmatites exposed in old prospect pits north of U. S. Highway 250, northwest of Centerville.

Amphibolite

Interlayered with the granite gneiss are units of amphibolite (R-4081) that in some areas can be traced for considerable distances. The units mapped as amphibolite are variable in composition, with amphibolite and hornblende gneiss being dominant. The amphibolite is generally well foliated and ranges from fine

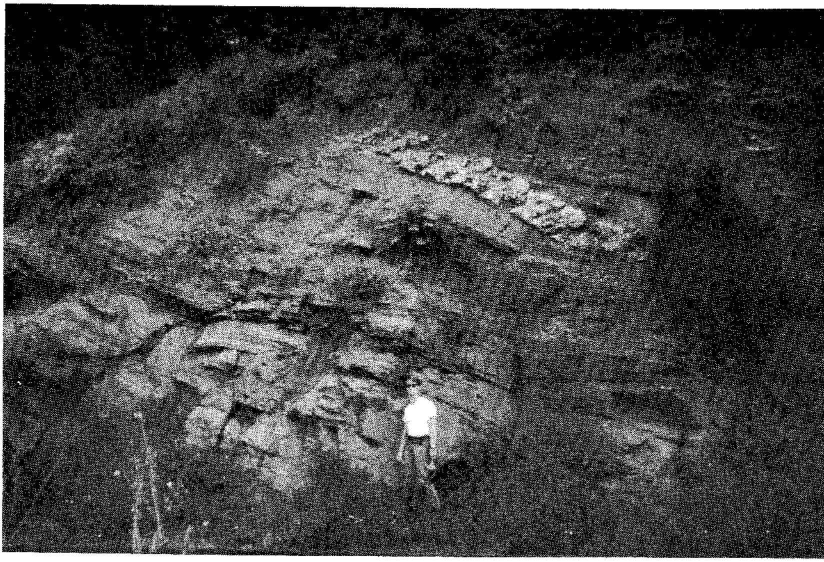


Figure 4. Slightly discordant pegmatite dike in granite gneiss; railroad cut east of Sabot (Plate 2). The lighter colored, 3-foot-wide dike is in upper right center of photograph.

to medium grained; occasional very coarse-grained phases are dominated by elongate hornblende crystals up to 0.75 inch in length. At some localities the rock is a uniform dark greenish-black with the foliation dictated by the parallel hornblende crystals; elsewhere, the rock has a pronounced compositional banding of alternating hornblende and plagioclase laminae. Foliation within the amphibolite is parallel to that of the surrounding gneiss. The amphibolite at some localities is cut by irregular veins of quartz (Figure 5). Although many outcrops within this unit are composed entirely of amphibolite, in some places amphibolite is interlayered with granite gneiss. This relationship may be seen in the western end of the railroad cut at Sabot where layers of amphibolite 2 or 3 feet thick lie between layers of granite gneiss; contacts between amphibolite and granite gneiss are sharp. The amphibolite is presumed to represent metamorphosed lava flows or beds of mafic pyroclastic debris.

Approximate mineral compositions are shown for three samples of amphibolite (Appendix II). Hornblende is the dominant constituent and plagioclase is also abundant. Quartz and potassic feldspar are present in lesser quantities, although in one thin section (R-3094) quartz was abundant. One section (R-3092) differed from the others in that it contained abundant pyroxene

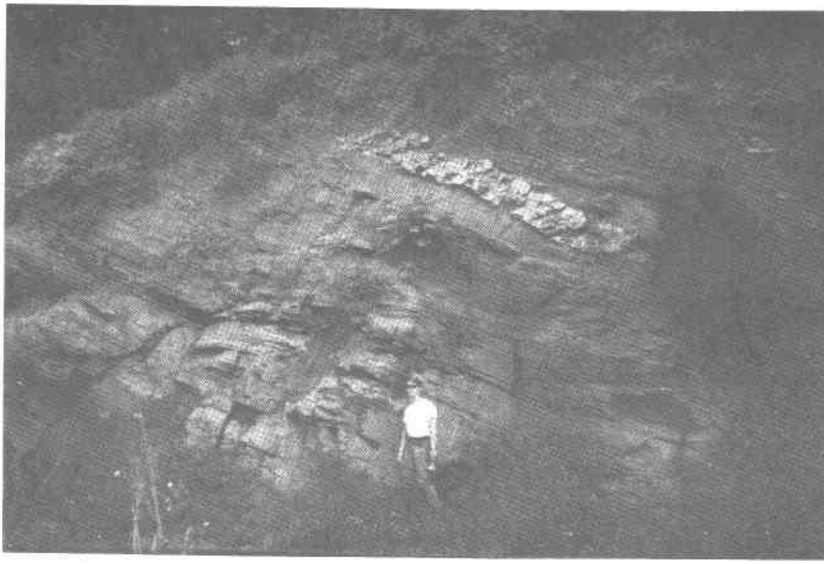


Figure 4. Slightly discordant pegmatite dike in granite gneiss; railroad cut east of Sabot (Plate 2). The lighter colored, 3-foot-wide dike is in upper right center of photograph.

to medium grained; occasional very coarse-grained phases are dominated by elongate hornblende crystals up to 0.75 inch in length. At some localities the rock is a uniform dark greenish-black with the foliation dictated by the parallel hornblende crystals; elsewhere, the rock has a pronounced compositional banding of alternating hornblende and plagioclase laminae. Foliation within the amphibolite is parallel to that of the surrounding gneiss. The amphibolite at some localities is cut by irregular veins of quartz (Figure 5). Although many outcrops within this unit are composed entirely of amphibolite, in some places amphibolite is interlayered with granite gneiss. This relationship may be seen in the western end of the railroad cut at Sabot where layers of amphibolite 2 or 3 feet thick lie between layers of granite gneiss; contacts between amphibolite and granite gneiss are sharp. The amphibolite is presumed to represent metamorphosed lava flows or beds of mafic pyroclastic debris.

Approximate mineral compositions are shown for three samples of amphibolite (Appendix II). Hornblende is the dominant constituent and plagioclase is also abundant. Quartz and potassic feldspar are present in lesser quantities, although in one thin section (R-3094) quartz was abundant. One section (R-3092) differed from the others in that it contained abundant pyroxene and minor amounts of calcite. Sphene and apatite are the most common accessory minerals. The specimens are characterized by a general absence of black opaque minerals. Garnet, up to approximately 0.5 inch in diameter, is present at several localities, particularly in the coarser portions of the unit.

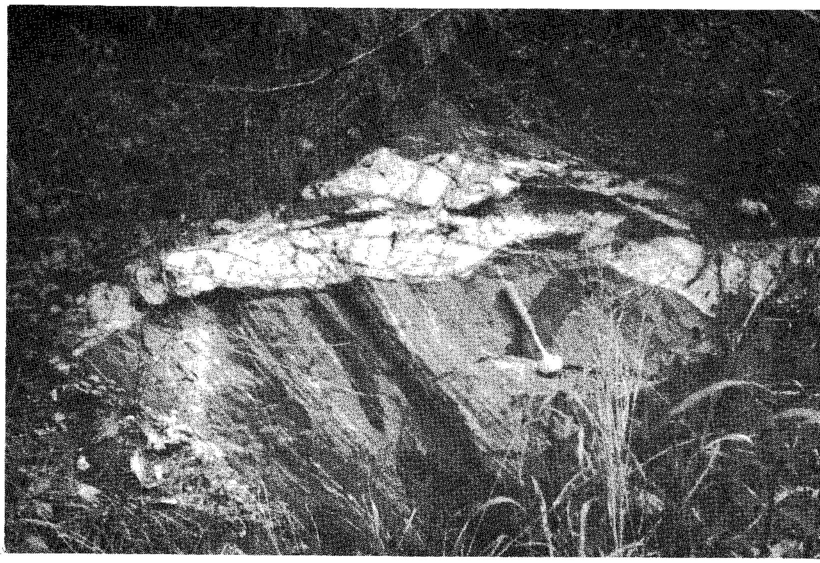


Figure 5. Well-foliated amphibolite cut by discordant, irregular quartz vein; railroad cut east of Sabot (Plate 2).

Whether all the amphibolite in the area is part of the same unit repeated by folding or whether it represents separate units interlayered with the granite gneiss could not be determined. However, it is believed that the northeastern outcrops of amphibolite are separate from the other occurrences, small segments of which are exposed at the surface in small doubly plunging folds.

PALEOZOIC ROCKS

Metavolcanic Rocks

The metavolcanic rocks occur as a northeastward-trending band averaging 1.5 miles in width. This unit borders the northern portion of the Richmond basin to the west and terminates southward at the north bank of the James River in an area of intense injection by the Petersburg granite. To the northeast it extends beyond the limits of the mapped area. Northeast of the Richmond basin few exposures are present, and placement of the and minor amounts of calcite. Sphene and apatite are the most common accessory minerals. The specimens are characterized by a general absence of black opaque minerals. Garnet, up to approximately 0.5 inch in diameter, is present at several localities, particularly in the coarser portions of the unit.

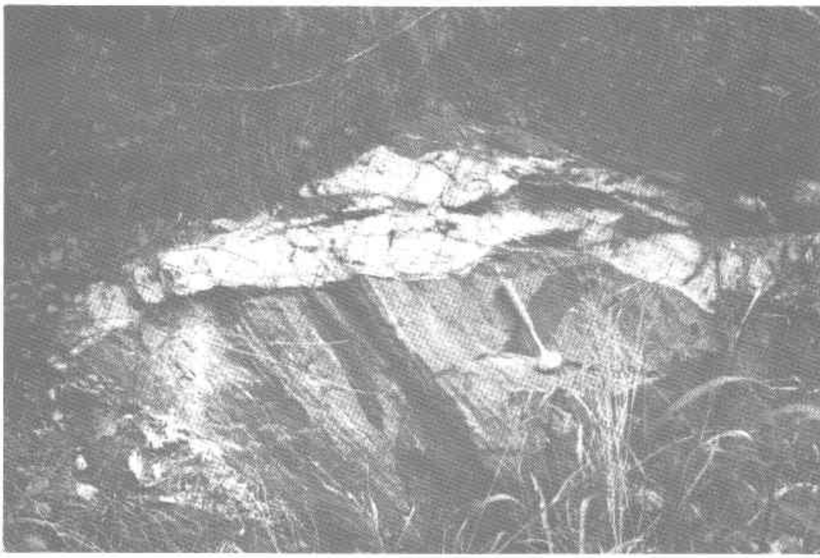


Figure 5. Well-foliated amphibolite cut by discordant, irregular quartz vein; railroad cut east of Sabot (Plate 2).

Whether all the amphibolite in the area is part of the same unit repeated by folding or whether it represents separate units interlayered with the granite gneiss could not be determined. However, it is believed that the northeastern outcrops of amphibolite are separate from the other occurrences, small segments of which are exposed at the surface in small doubly plunging folds.

PALEOZOIC ROCKS

Metavolcanic Rocks

The metavolcanic rocks occur as a northeastward-trending band averaging 1.5 miles in width. This unit borders the northern portion of the Richmond basin to the west and terminates southward at the north bank of the James River in an area of intense injection by the Petersburg granite. To the northeast it extends beyond the limits of the mapped area. Northeast of the Richmond basin few exposures are present, and placement of the contact between the metavolcanic rocks and Petersburg granite is inferred.

The metavolcanic rocks are believed to be younger than the gneiss to the west. Structural details indicate that metavolcanic rocks lie in a synclinal trough on top of the gneisses, and the contact appears to be unconformable, as indicated by the truncation of the eastern amphibolite and biotite gneiss units and by the discordance of foliation and lineation between the metavolcanic rocks and the gneisses. In exposures near this contact there were no indications of faulting.

Metavolcanic rocks (R-3102) are well exposed in the Royal Stone quarry of Vulcan Materials Company at Hylas where several phases are present. The predominant rock type is a gray-green, fine-grained, dense metarhyolite that is highly fractured by closely spaced joint sets and has a conspicuous foliation; locally it is well bedded. In some areas small crenulations on the foliation surfaces provide a well-developed lineation. Other varieties of the unit include a very fine-grained, dark green-black phyllitic rock and a coarser gneissic phase with conspicuous pink orthoclase augen up to 0.5 inch in diameter. Bedding, particularly near the base of the quarry, is intensely contorted and numerous small tight folds, most of which are overturned, are present.

Several thin sections of the metavolcanic rocks have been examined, and approximate mineral compositions of three samples are given in Appendix II. All of the analyses are of coarser grained lithologies. Quartz and potassic feldspar are the most abundant minerals in the metavolcanic rocks, although plagioclase feldspar is also present. Muscovite is a common constituent, and much of it is finely divided and parallel to the flow lines that are accentuated by streaks of black opaque minerals. Muscovite also occurs as large porphyroblasts that have a well-developed cleavage commonly at an angle of 5 to 10 degrees with the flow lines that bend around the porphyroblasts. The divergence of flow lines is even more conspicuous where they are distorted around large porphyroblasts of potassic feldspar. Many of these have corroded edges and some are highly sericitized. Quartz occurs primarily as fine grains between the porphyroblasts of feldspar and exhibits pronounced strain shadows and undulatory extinction; stringers of finely divided quartz grains tend to align parallel to the flow banding of the rock. The quartz grains are generally anhedral, and much of the rock appears to have a cataclastic texture. This unit is believed to represent former volcanic rocks that have been devitrified and metamorphosed.

One conspicuous feature of the metavolcanic rocks is their tendency to be closely jointed. Generally two or more well-developed joint sets cut the rock, resulting in the development of tabular fragments that have a characteristic light-tan color. In some areas these fragments can be traced in the soil of plowed fields or along road cuts, thereby serving as an aid in mapping the extent of the metavolcanic rocks. The closely spaced joints aid in distinguishing the metavolcanic rocks from the granite gneiss that characteristically has fewer, more widely spaced, and less conspicuous joints.

Petersburg Granite

The Petersburg granite occurs primarily in the eastern portion of the area. It is bounded on the west by rocks of Triassic age in the Richmond basin and on the north by metavolcanic rocks. As summarized by Bloomer (1939, p. 142-143), the Petersburg granite consists of three phases: a gray to pink, medium-grained granite; a blue, relatively fine-grained facies; and a porphyritic facies that occurs adjacent to the Richmond basin.

Two phases of the Petersburg are dominant within the mapped area. The most abundant is a uniform to slightly porphyritic, medium-grained, gray to pink granite (R-3098); foliation is inconspicuous although in some exposures a faint foliation is present. This phase of the Petersburg (R-3100) is exposed in the bed of a small stream on the east side of Gayton Road about 0.8 mile southwest of its junction with U. S. Highway 250 (Plate 1).

At the contact between the granite and Triassic rocks just south of U. S. Highway 250, about 0.4 mile west of its junction with Gayton Road (Plate 1), the Petersburg (R-3104) is characterized by a pronounced foliation and pink orthoclase phenocrysts over 1 inch in length. Most of the orthoclase phenocrysts are parallel or subparallel to the foliation and are enclosed in a medium-grained groundmass of anhedral quartz and plagioclase crystals. This rock is composed of 24.9 percent quartz, 38.6 percent orthoclase, 34.6 percent plagioclase, and 1.9 percent mafic minerals; therefore, it is a quartz monzonite porphyry. The same lithology is exposed east of Midlothian (R-4082), and a large exposure occurs along the tracks of the Southern Railway northeast of Midlothian (R-4084). It is restricted to the immediate vicinity of the eastern border of the Richmond basin. On Plates

1 and 2 this unit has been mapped separately as quartz monzonite porphyry.

The Petersburg granite is cut by numerous joints, many of which are filled with pegmatitic material or, more commonly, quartz. In weathered exposures the quartz veins stand out in relief and may be an aid in distinguishing between the weathered granite and the adjacent weathered arkose of Triassic age.

TRIASSIC SYSTEM

The sedimentary rocks in the Richmond basin are deeply weathered and fresh exposures are rare. These rocks occur in the northern portion of a Triassic basin that extends southward approximately 30 miles and reaches a maximum width of about 9 miles. Detailed investigations of the coal-bearing sequence have been made by Ashburner (1888), Shaler and Woodworth (1899), Woodworth (1902), and Roberts (1928); most of the earlier reports emphasized the coals and fossils.

Within the area of this report, four Triassic sedimentary units could be distinguished. These units are: (1) coal measures, (2) coarse conglomerates, (3) shale, and (4) interbedded shale and sandstone. In the area mapped as shale, thin beds of arkosic sandstone are interbedded with the shale, but shale dominates. In the area mapped as shale and sandstone, both units occur in approximately equal amounts.

Coal Measures

Coal is present along both the eastern and western margins of the Richmond basin. On the eastern margin coal occurs northward from the James River to the junction of Church Road and Gayton Road (Plates 1, 2). Numerous banks of coal debris line Gayton Road south of this junction, and fossils of plant stems and leaves occur in some of the fragments of coal, shale, and fine-grained carbonaceous sandstone (R-4091) in these heaps. In the woods on either side of the road are many shallow prospect pits, and east of the road are two large pits from which coal was formerly removed. In the area north and northwest of Church Road, no coal deposits or indications of coal workings could be found. Instead, the Petersburg granite is overlain by arkosic sandstone and shale. It is assumed that the coal deposits terminate northward by a facies change in the southern portion of the Hylas quadrangle.

South of the James River on the eastern margin of the Richmond basin, coal (R-4089) is exposed in a band about 0.3 mile wide that extends to the southern boundary of the mapped area (Plate 2). Numerous old prospect pits and abandoned mines occur in this vicinity, and fragments of coal, shale, and arkosic sandstone are present in the waste heaps adjacent to these pits and mines. Coal occurs east of its normal outcrop area at two localities along this trend. Near Blackheath Pond the coal measures have been offset to the east by normal faulting that has produced a small graben-like structure. Where U. S. Highway 60 crosses Falling Creek a small coal basin is completely separated from the main body of Triassic rocks. This basin is bounded to the west by a normal fault and is nonconformable upon the Petersburg granite to the east. Coals also occur on the western edge of the Richmond basin but are more limited in extent. They terminate north of Manakin by a facies change, and south of State Road 711 the coal measures are truncated by faults (Plate 2).

The coal measures are composed of coal interbedded with arkosic sandstone and shale. Coal beds up to 12 feet thick have been reported from the old mines but they are generally much thinner; in many places coal occurs as seams only 1 or 2 inches thick. Several stratigraphic sections within the coal measures were reported by Roberts (1928, p. 100-102). A measured stratigraphic section of a relatively coal-deficient portion of the coal measures exposed in a cut along Gayton Road (Plate 2) is given in Table 2. The coal is largely bituminous and when fresh is black with a brilliant luster. It is generally well jointed and tends to break into angular blocks. In outcrop the coal is more resistant to weathering than the surrounding shales; it weathers to a dark brown. Much of the shale associated with the coal measures is carbonaceous, and all gradations between carbonaceous shale and coal are present.

Sandstone and Shale

In the area of study, sandstones and shales are the major lithologies in the Richmond basin. Most of the sandstones are arkosic and contain muscovite (R-3105). Those in contact with the Petersburg granite at the border of the basin are arkoses. The sandstones range from fine to coarse grained and are gray when fresh (R-4087). Some are conglomeratic with rounded quartz pebbles (R-4086). Upon moderate weathering they become yellowish brown, and deep weathering produces a mottled yellowish brown and Indian red. Even when deeply weathered, flecks of muscovite are conspicuous within the sandstone. Bedding is generally massive, and many weathered exposures have nearly vertical joints. Some of the sandstones are channelled and some have cross-bedding.

Table 2. — Measured stratigraphic section within Triassic coal measures along Gayton Road, 0.8 mile west of eastern margin of Midlothian quadrangle (Plate 2).

Lithology	Thickness (Feet)
Sandstone, arkosic, yellow-brown to reddish-brown, coarse-grained	2.0
Coal, dark-brown, clayey, indistinctly bedded	1.2
Shale, dull-brown to dark-brown, micaceous, carbonaceous throughout, gradational into overlying coal	1.3
Shale, dull-brown to dark-brown, micaceous	0.8
Shale, grayish-brown, micaceous, fissile	0.2
Shale, massive, thinly laminated, yellowish-brown, micaceous	1.5
Sandstone, arkosic, yellow-brown to reddish-brown, coarse-grained, lensoidal	0.4
Shale, gray to yellowish-brown, finely micaceous	0.8
Nodular zone: limonitic nodules, concentrically weathered	0.5
Shale, gray to yellowish-brown, slightly feldspathic, micaceous, slightly carbonaceous	0.8
Mudstone, massive-bedded, coarsely micaceous, feldspathic	5.5
Shale, gray mottled with hematitic-red, massive	3.2
Sandstone, arkosic, hematitic-red, fine-grained	1.0
Shale, light-gray mottled with reddish-brown, coarsely laminated, slightly silty	6.9
Shale, black and yellowish-brown, carbonaceous, blocky, coaly	0.8
Coal, lustrous, thinly laminated	0.6

Lithology	Thickness (Feet)
Shale, light-gray mottled with reddish-brown, coarsely laminated, slightly silty	4.8
Sandstone, arkosic, white and black speckled, weathered yellowish-brown, fine- to medium-grained	0.3
Shale, gray to brown, finely laminated, contains plant fragments	0.3
Sandstone, arkosic, yellowish-brown, micaceous, fine- to coarse-grained, carbonaceous, shaly parting in center	1.0
Shale, brown to gray, local ferruginous zones, finely laminated, micaceous	5.4
Sandstone, arkosic, yellowish-brown, micaceous, fine- to coarse-grained	0.7
Shale, brown to gray, local ferruginous zones, finely laminated, micaceous	2.0
Total	42.0

In many areas the contact between the Triassic arkose and the Petersburg granite is difficult to discern. The mineralogy of the arkose and the granite are nearly identical and the grain size may be similar; therefore, it is difficult to distinguish between the two rock types even in fresh exposures. Most of the exposures are highly weathered. The only conclusive evidence is the presence of rounded mineral grains which indicate a sedimentary origin. One additional criterion that is useful in distinguishing the two lithologies in weathered exposures is that the granite contains numerous quartz veins whereas there are none in the arkose. Generally the border arkose is slightly conglomeratic, and the large rounded grains serve to indicate the sedimentary origin of the rock.

In general, the shales are well exposed only where they are interbedded with standstones because thick shale sequences are deeply weathered and exposures of them are rare. This lithology varies from a dark-gray, highly carbonaceous, fissile shale with abundant plant fragments to a brownish-red, highly fissile shale. Carbonaceous shale is exposed at several places in the bed of the intermittent stream that is crossed by State Highway 6, 0.7 mile east of Manakin (Plate 2). Much of the gray shale is micaceous. Red shale appears to be more abundant near the center of the Richmond basin. Upon weathering, the gray shale becomes a mottled yellowish-brown and Indian-red clay, whereas the red shale becomes a deep-red clay. A measured stratigraphic section of interbedded Triassic shale and sandstone is given in Table 3.

Table 3. — Measured stratigraphic section at northeast end of Lake Salisbury about 2 miles north-northwest of Midlothian (Plate 2).

Lithology	Thickness (Feet)
Tertiary gravel (24.5 feet)	
Gravel, very coarse with cobbles, highly limonitized with sandy matrix	7.5
Gravel, very coarse with cobbles, moderately limonitized	17.0
Triassic shale and sandstone (60.0 feet)	
Sandstone, hematite-red to olive-brown, thin-bedded with some thin shale laminae	8.5
Shale, gray, laminated, weathers deep red in upper part	3.0
Sandstone, hematitic-red with splotches of yellow-brown, fine-grained, massive, arkosic, micaceous, with cross-bedding, channelled, some carbonaceous streaks, nearly vertical clay-filled joints prominent	13.0
Shale, mottled pale olive-drab to deep-red, very micaceous	19.0
Sandstone, arkosic, mottled yellowish-red to hematitic-red, micaceous, fine-grained	1.5
Shale, mottled yellowish-brown to hematitic-red	0.3
Sandstone, arkosic, hematitic-red, fine-grained	2.5
Shale, mottled yellowish-brown and hematitic-red	5.5
Sandstone, gray, organic-rich	1.5
Shale, mottled yellowish-brown and hematitic-red, sandy, micaceous	5.2

Conglomerate

Well-developed conglomerates occur both on the eastern and western borders of the Richmond basin. Those on the eastern border are a few hundred feet southwest of where U. S. Highway 250 crosses a tributary to Little Tuckahoe Creek east of the Henrico-Goochland county boundary (Plate 1). They occur as prominent outcrops on a pasture slope near a contact between Triassic sedimentary rocks and Petersburg granite. The contact, which is within a 15-foot-wide covered interval between porphyritic granite on one side and conglomeratic sandstone on the other, appears to be a nonconformity. The conglomerate is interbedded with medium- to coarse-grained gray sandstone and contains cobbles that average 3 inches across and boulders that are more than 1 foot in diameter. The cobbles and boulders are predominantly of granite, although some of the smaller pebbles are of quartz; the larger fragments are well rounded. The sandstones, some of which are cross bedded, are conglomeratic and contain scattered rounded quartz pebbles. Conglomerate is also present along the eastern border of the Richmond basin on the tributary of Little Tuckahoe Creek south of Kain Road (Plate 1). There, cobbles occur within the Triassic rocks immediately overlying the Petersburg granite, but cannot be traced laterally along the contact.

A very coarse boulder conglomerate occurs along much of the western margin of the Richmond basin north of the James River. Highly angular boulders, some of which exceed 2 feet in diameter, are mixed with smaller angular fragments and are enclosed in a matrix of hematitic arkosic sandstone and shale. The large angular boulders commonly consist of metavolcanic rocks, but boulders of granite gneiss and biotite gneiss also occur. This lithology is deeply weathered and many of the boulders have been converted to saprolite, so that their outlines can be discerned only with difficulty. The angular nature of the boulders suggests that they have been transported only a short distance. A similar coarse boulder conglomerate is exposed locally a short distance west of the Richmond basin in shallow roadcuts along State Road 623 a few hundred feet north of its intersection with U. S. Highway 250 (Plate 1). These conglomerates were noted by Shaler and Woodworth (1899, p. 424 and Pl. XXII). The boulders are primarily of granite gneiss, and some of them attain lengths of 6 feet.

Weathered, well-bedded conglomerate that is 3 feet thick and consists primarily of granite gneiss cobbles is present in the roadcut along State Road 623 about 1.2 miles south of its intersection with U. S. Highway 250 (Plate 1). The beds dip gently toward the southeast.

A small area is underlain by conglomerate near the center of the Richmond basin; this lithology is exposed in a cut along State Road 711 immediately west of Bernards Creek and in cuts along State Road 607 south of its junction with State Road 711 (Plate

2). Where reasonably fresh, this conglomerate is well cemented and contains an abundance of rounded quartz pebbles that are up to 2 inches in diameter. The pebbles occur in a sandy matrix and the conglomerate is interbedded with medium-grained sandstone.

Diabase Dikes

Diabase dikes cut the Triassic sedimentary rocks and at a few localities they occur in the metavolcanic rocks. Because of intense weathering the dikes generally are not exposed, but their presence is indicated by boulders of dense, dark diabase. Many of these boulders are 2 or more feet across, and their outer surfaces have been weathered to a deep red-brown crust; however, some of the interiors consist of relatively fresh diabase. In some places the boulders occur as clusters in a stream bed or have a crude alignment on a slope.

At only one exposure can the actual dikes be observed. This is in the Royal Stone quarry of Vulcan Materials Company at Hylas where three diabase dikes are present. The largest is 5 feet across and has prominent chilled zones at its borders. This dike, well exposed on the lower levels of the quarry walls and on the benches, narrows to a width of 2 feet within a distance of 100 feet along its length, and on the opposite wall of the quarry, another 100 feet away, it is not visible. It also appears to become narrower downward. The dikes have not been metamorphosed and the exposed dikes, which are discordant to the country rock, are composed of fine- to medium-grained, dense, dark-gray diabase (R-3103). The unmetamorphosed nature and cross-cutting relations of the diabase dikes indicate that they were intruded after the deposition of the Triassic sediments and that this intrusion extended beyond the borders of the Richmond basin into the adjacent metavolcanic rocks.

TERTIARY SYSTEM

Gravels

Two distinct units of Tertiary gravels occur within the area of this report, mainly in the Midlothian quadrangle. Although both are composed primarily of coarse gravels, and form very gently inclined units, they occur at strikingly different elevations and differ in degree of weathering and cementation. The age of neither is known but since they both appear to be older and occur at higher elevations than the Quaternary alluvium, they are tentatively designated as Tertiary. The higher gravel is believed to be the older.

The higher gravel is widespread on the relatively flat upland surfaces west and north of Midlothian (Plate 2). A deep roadcut along U. S. Highway 60 just east of the Midlothian quadrangle contains a 25-foot-thick exposure of nearly horizontal, massively bedded, coarse gravels overlying Petersburg granite with the contact at an elevation of about 330 feet. A roadcut at the intersection of U. S. Highway 60 and State Road 652, just north of Mt. Sinai Church (Plate 2), exposes a 20-foot thickness of coarse gravels (Figure 6) that contain interbeds of clay ranging in width from less than an inch up to 2 feet. At this locality the gravels overlie deeply weathered Triassic shale in an angular unconformity, and the contact is at an elevation of about 385 feet. A large exposure of gravel occurs at an elevation of about 340 feet, east of the spillway of Lake Salisbury, about 2 miles north-northwest of Midlothian (Plate 2), where a 25-foot-thick sequence of gently inclined coarse gravels overlies weathered Triassic shale and sandstone in an angular unconformity (Figure 7). These gravels are highly limonitized and consist of rounded cobbles up to 8 inches in diameter in a sandy matrix (Figure 8).

Figure 6. Coarse Tertiary gravels overlying Triassic shale in angular unconformity; intersection of U. S. Highway 60 and State Road 652 (Plate 2).

In general the gravels occur as a veneer, up to 40 feet thick, deposited on a nearly planar surface. They are present in nuare tentatively designated as Tertiary. The higher gravel is believed to be the older.

The higher gravel is widespread on the relatively flat upland surfaces west and north of Midlothian (Plate 2). A deep roadcut along U. S. Highway 60 just east of the Midlothian quadrangle contains a 25-foot-thick exposure of nearly horizontal, massively bedded, coarse gravels overlying Petersburg granite with the contact at an elevation of about 330 feet. A roadcut at the intersection of U. S. Highway 60 and State Road 652, just north of Mt. Sinai Church (Plate 2), exposes a 20-foot thickness of coarse gravels (Figure 6) that contain interbeds of clay ranging in width from less than an inch up to 2 feet. At this locality the gravels overlie deeply weathered Triassic shale in an angular unconformity, and the contact is at an elevation of about 385 feet. A large exposure of gravel occurs at an elevation of about 340 feet, east of the spillway of Lake Salisbury, about 2 miles north-northwest of Midlothian (Plate 2), where a 25-foot-thick sequence of gently inclined coarse gravels overlies weathered Triassic shale and sandstone in an angular unconformity (Figure 7). These gravels are highly limonitized and consist of rounded cobbles up to 8 inches in diameter in a sandy matrix (Figure 8).

Figure 6. Coarse Tertiary gravels overlying Triassic shale in angular unconformity; intersection of U. S. Highway 60 and State Road 652 (Plate 2).

In general the gravels occur as a veneer, up to 40 feet thick, deposited on a nearly planar surface. They are present in nu-

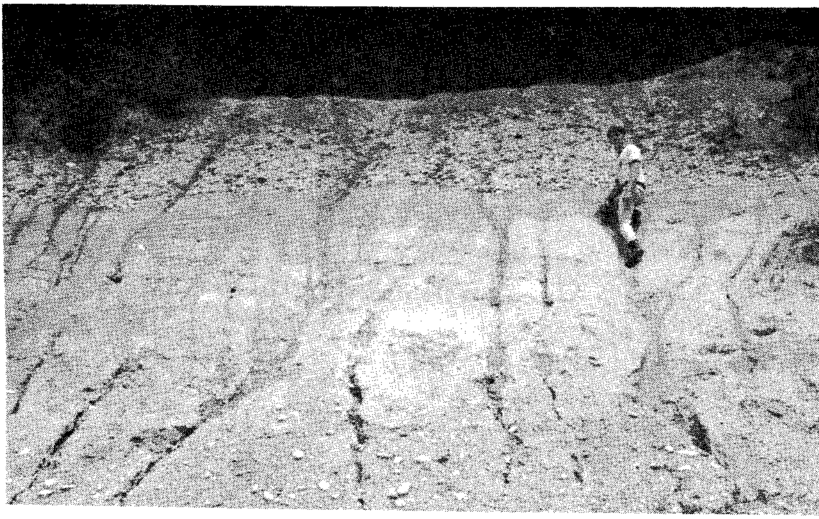


Figure 7. Coarse Tertiary gravels overlying Triassic shale and arkosic sandstone in angular unconformity; northeast end of Lake Salisbury, about 2 miles north-northwest of Midlothian (Plate 2).

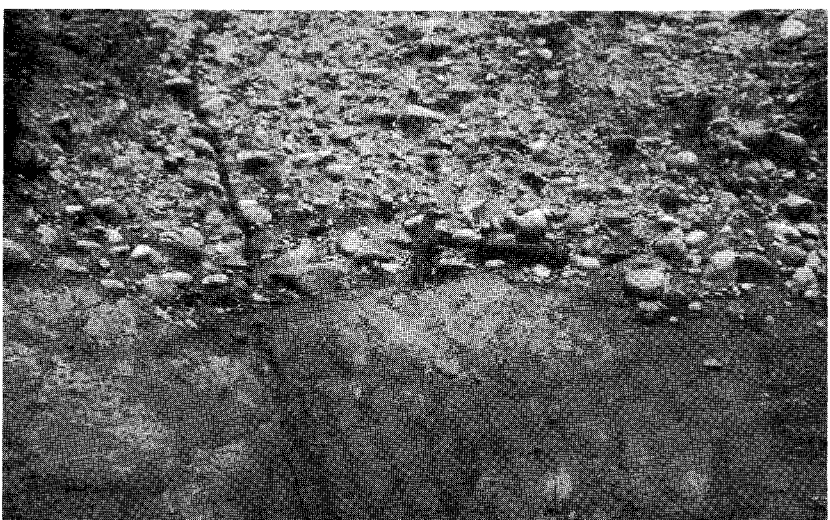


Figure 8. Contact between coarse Tertiary gravels and Triassic arkosic sandstone; northeast end of Lake Salisbury, about 2 miles north-northwest of Midlothian (Plate 2). Rounded cobbles up to 8 inches in diameter occur in a limonitic sandy matrix.

merous roadcuts and in wells drilled on the upland surfaces. The contact between gravel and underlying rocks is gently inclined

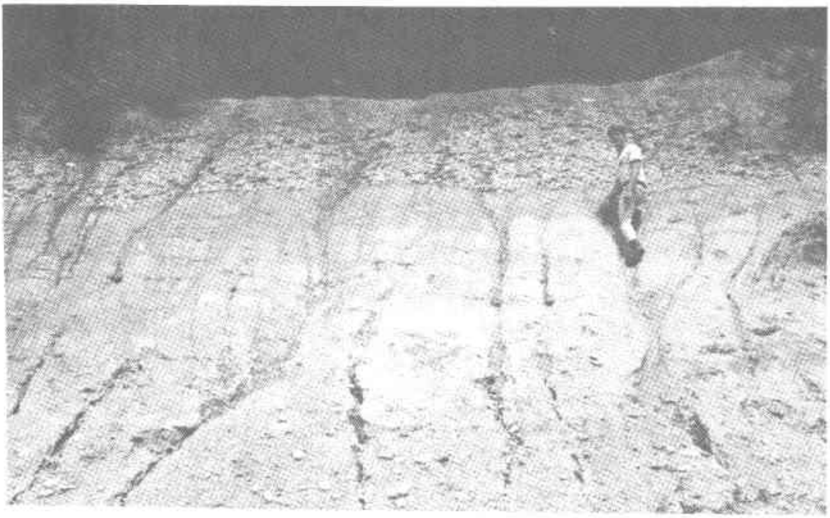


Figure 7. Coarse Tertiary gravels overlying Triassic shale and arkosic sandstone in angular unconformity; northeast end of Lake Salisbury, about 2 miles north-northwest of Midlothian (Plate 2).

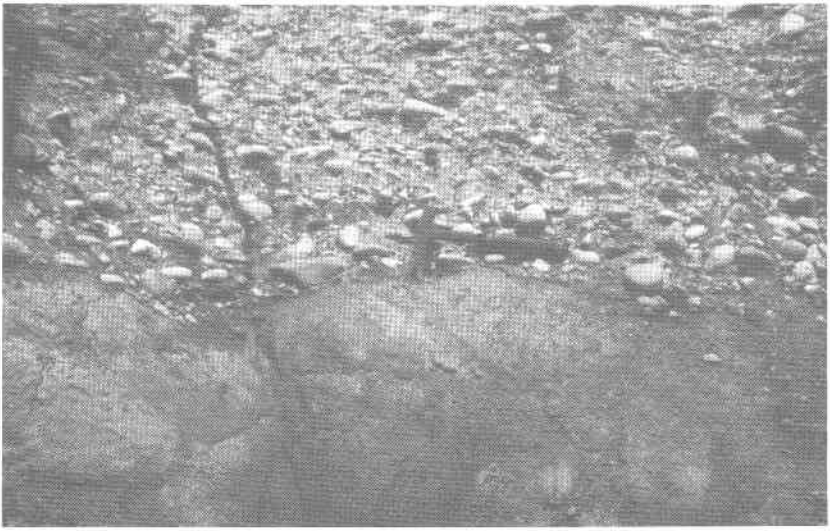


Figure 8. Contact between coarse Tertiary gravels and Triassic arkosic sandstone; northeast end of Lake Salisbury, about 2 miles north-northwest of Midlothian (Plate 2). Rounded cobbles up to 8 inches in diameter occur in a limonitic sandy matrix.

merous roadcuts and in wells drilled on the upland surfaces. The contact between gravel and underlying rocks is gently inclined toward the east or east-northeast at a gradient of about 9 feet per mile, and is generally marked by a pronounced break in slope of the topography.

The gravels are unsorted and bedding is poorly defined except where thin interbeds of clay occur. The matrix is commonly sandy but contains varying amounts of clay, with clay being dominant in some places. Where weathered, the matrix is yellowish brown to brownish red, and many of the cobbles have a brownish-red surface stain. The matrix in such outcrops may be partially cemented, largely by limonite. Relatively unweathered samples taken from drillholes have a light-tan, generally sandy matrix. The larger components in the gravel range from granules to large cobbles, and cobbles about 3 to 4 inches in diameter dominate many outcrops. The cobbles are composed primarily of quartz and light-tan to white quartzite and are well rounded. Scattered elliptical cobbles have their long axes oriented approximately parallel to bedding. Many of the quartzite cobbles are weathered and upon removal may easily be reduced to a mound of fine white sand.

The lower Tertiary gravels occur primarily overlying relatively flat terrace remnants adjacent to the James River. They are present both south and north of the James River, and overlie the older rocks in an angular unconformity. In general their base is inclined toward the river where the lower contact is locally at a minimum elevation of 140 feet. More generally it lies between 150 and 180 feet nearest the river, and away from the James River the lower contact rises gradually at a slope of about 50 feet per mile to a maximum elevation of over 300 feet. The gravel, which averages about 25 feet in thickness, attains a maximum thickness of 70 feet.

Coarse gravels dominate this unit. Although cobbles up to 7 inches in diameter occur, the average diameter is approximately 3 inches. South of the James River, these gravels are well exposed in a cut along State Road 711, 0.15 mile east of where it crosses Norwood Creek. A gravel pit at the intersection of State Roads 650 and 647, north of the James River, also contains these gravels (Plate 2). The gravels are interlayered with clayey sand beds up to 8 feet in thickness, although most are less than 1 foot thick. Elongate cobbles are oriented with their long axes parallel to the bedding. Cobbles and pebbles are composed dominantly of quartz and are relatively fresh and little weathered compared to similar particles in the higher gravels. Outcrops of this unit, which are common in roadcuts, are generally highly oxidized and are characterized by a bright Indian-red color. Fresher samples obtained from drill holes have a mottled Indian-red and yellowish-brown matrix. The matrix is dominantly sandy and contains varying amounts of clay; the gravels generally are not cemented. The clayey sand beds have a similar mottled color and contain a few rounded quartz granules.

QUATERNARY SYSTEM

Alluvium

The flood plain of the James River is floored with alluvial deposits as are some areas adjacent to Bernards Creek, Norwood Creek, and Tuckahoe Creek. This alluvium is composed of stratified sand, silt, clay, and gravel.

STRUCTURAL GEOLOGY

MINOR FEATURES

Foliation

Foliation, consisting of compositional banding or gneissose texture, is commonly well developed and has a similar trend in the granite gneiss, biotite gneiss, and amphibolite. In the metavolcanic rocks, foliation may be either compositional banding or cleavage, depending upon whether it is a gneissic phase or a more phyllitic portion. The cleavage is a flow cleavage or schistosity that is parallel to the compositional banding of the gneissic phases. Some of the metavolcanic rocks have bedding that is commonly less than 1 inch thick, and may be obscured by the cleavage. In some of the minor folds in metavolcanic rocks at the Royal Stone quarry of Vulcan Materials Company, and in some minor folds in the gneisses, a poorly developed fracture cleavage has formed parallel to the axial plane of the folds. Because the folds are nearly isoclinal, this cleavage, where present, is parallel or subparallel to the foliation on the limbs of the folds and cannot be distinguished from it. Examples of folded foliation on a small scale can be observed in the metavolcanic rocks of the Royal Stone quarry of Vulcan Materials Company at Hylas and in some individual gneissic outcrops.

In order to compare foliation in the metavolcanic rocks and other foliated units, poles of foliation planes were plotted on the lower hemisphere of equal-area projections and the resulting plots were then contoured (Figures 9 and 10). The gneisses and amphibolite have a uniformity of foliation (Figure 9) although there is a slight variation in the strike. The dominant direction of strike centers around N.23°E. with a range between about N.40°E. and N.35°W. Dips are dominantly to the east, commonly averaging 30 degrees, but range from 10 to 65 degrees. A minor number of foliation planes have dips to the west as indicated.

In general, foliation in the metavolcanic rocks has a more restricted and different strike than in the gneiss (Figure 10). Here the strike has a dominant orientation of N.30°E. with

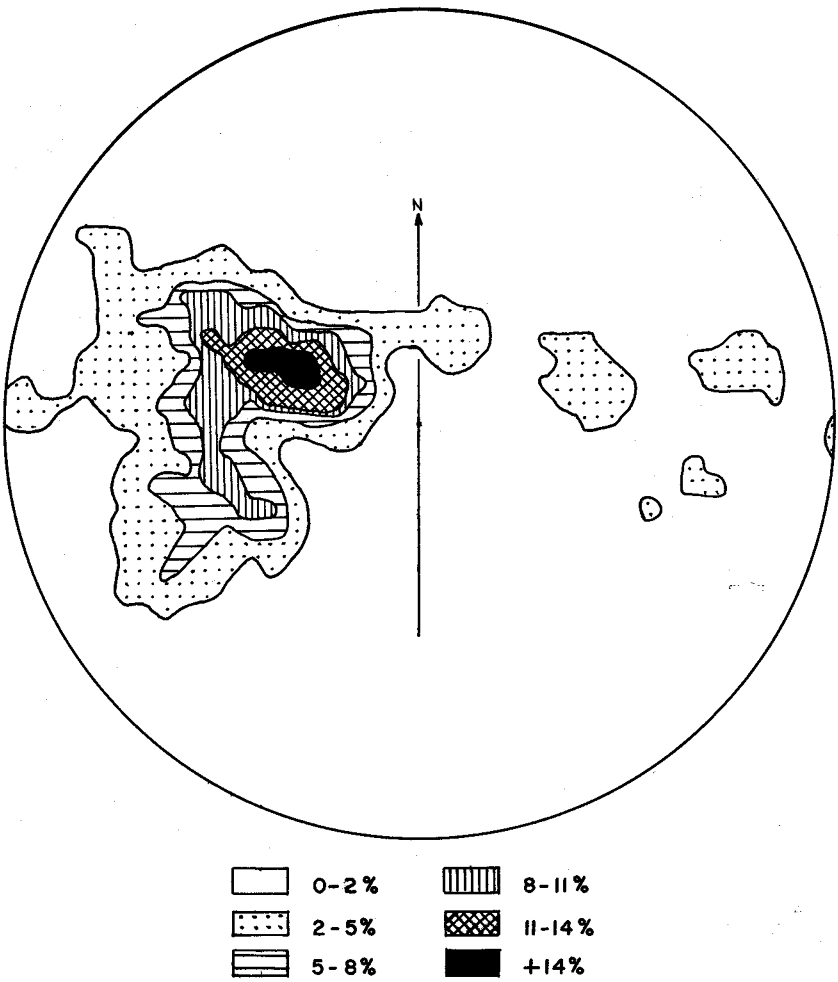


Figure 9. Contour diagram illustrating attitudes of foliation in granite gneiss, biotite gneiss, and amphibolite in the Hylas quadrangle. Lower-hemisphere plot based on 86 attitudes.

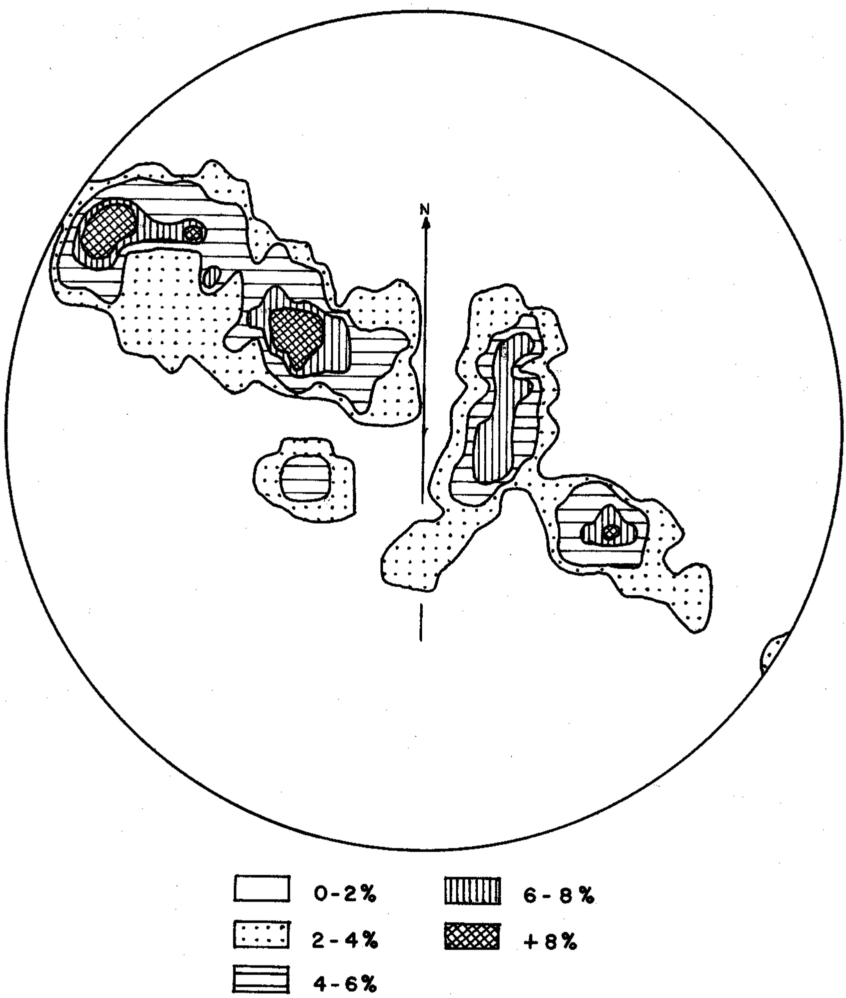


Figure 10. Contour diagram illustrating attitudes of foliation in metavolcanic rocks in the Hylas quadrangle. Lower-hemisphere plot based on 60 attitudes.

major deviations ranging between N.50°E. and N.45°W. The most dominant dip direction is to the east but a great number of foliation planes also dip to the west. Dip angles are variable with concentrations centering around 80°SE., 32°SE., 15°NW., and 43°NW.

A comparison of Figures 9 and 10 illustrates the differences between foliation attitudes in the gneisses and amphibolite and in the metavolcanic rocks. Major differences can be summed up as follows: (1) the dominant direction of strike is 8 to 10 degrees more easterly in the metavolcanic rocks; (2) variations in direction of strike are more common in the gneisses, with a dominance of northwesterly strikes occurring in that unit; (3) the direction of dip is primarily to the east in the gneisses, whereas in the metavolcanic rocks both easterly and westerly dips are common; and (4) there is a variation in dip angles in the metavolcanic rocks whereas in the gneisses dips are steep.

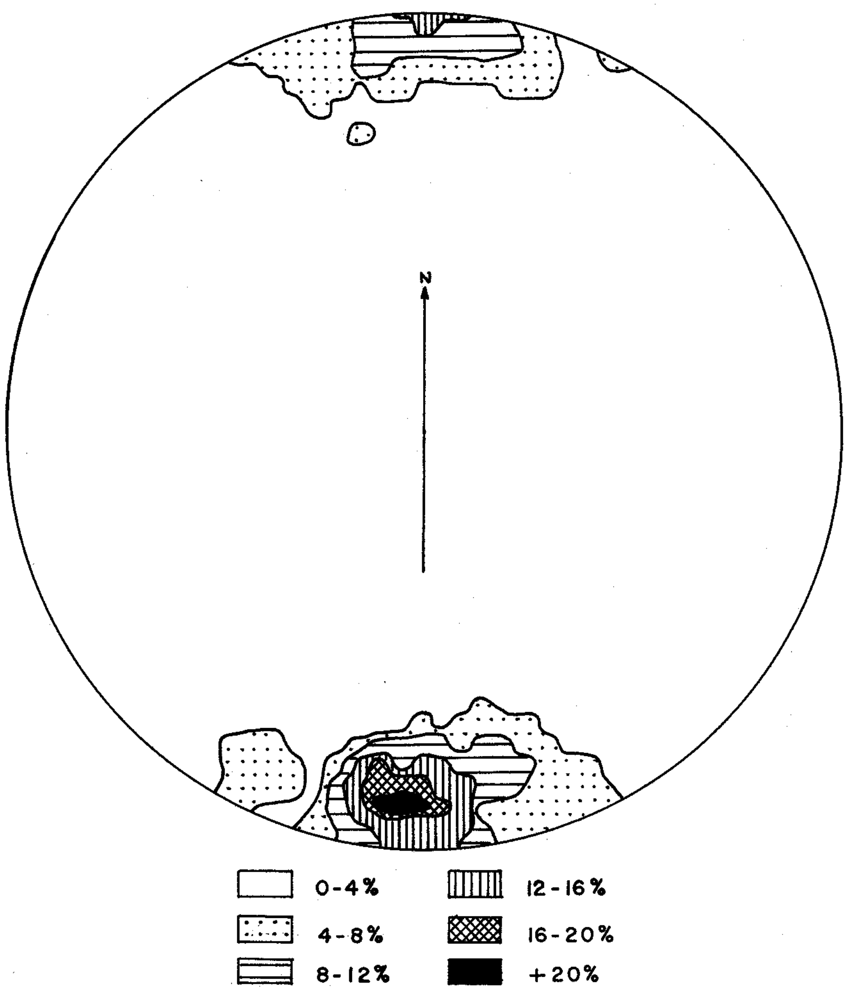


Figure 11. Contour diagram illustrating attitudes of lineations in granite gneiss, biotite gneiss, and amphibolite in the Hylas quadrangle. Lower-hemisphere plot based on 47 attitudes.

Lineation

Lineations are well developed in the metavolcanic rocks and in the gneisses. Two major types of lineation occur: (1) those formed by the parallel crests and troughs of tiny crenulations on the foliation surface, and (2) parallelism of linear minerals within the rocks. These lineations, where observed in conjunction with minor folds, appear to have formed in the *b* direction of these folds, parallel to the fold axes. It is assumed that they are

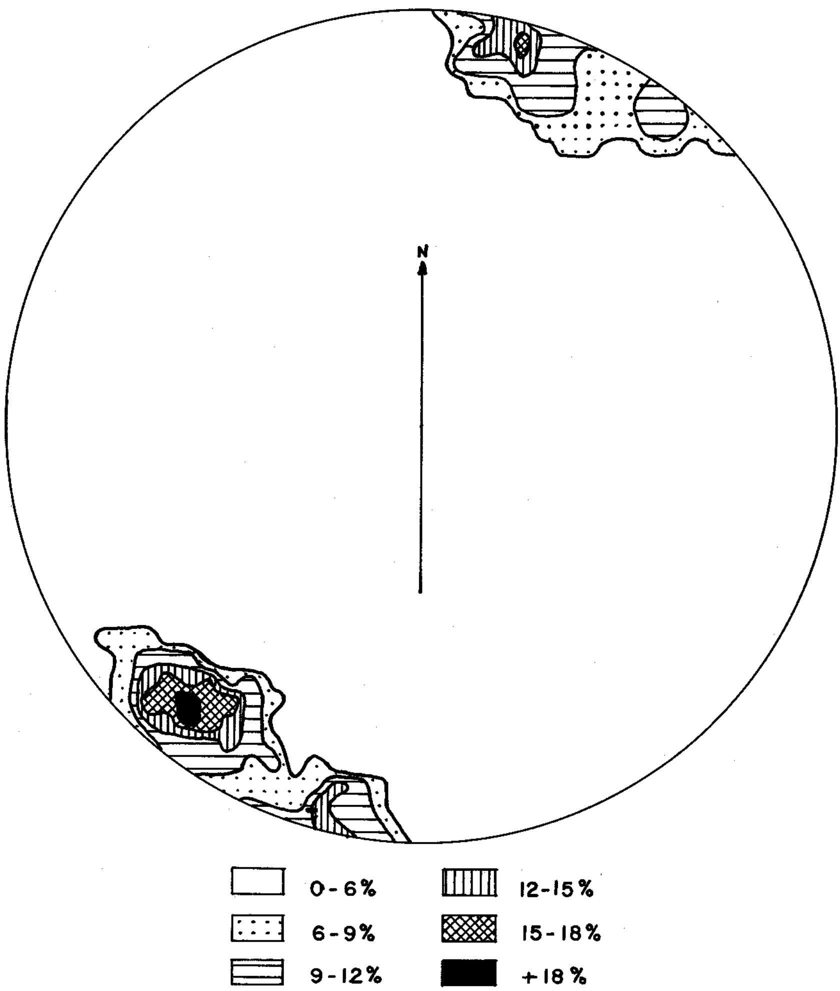


Figure 12. Contour diagram illustrating attitudes of lineations in metavolcanic rocks in the Hylas quadrangle. Lower-hemisphere plot based on 32 attitudes.

also parallel to the *b* direction of regional folding. Lineations of the first type are most prevalent in the metavolcanic rocks, and mineral lineations are more common in the gneisses.

Lineations in both gneiss and metavolcanic rocks have a limited range of orientation. In the gneisses and amphibolite, plunge directions of lineations range from N.30°E. to N.20°W., with the dominant direction almost north-south. Amount of plunge ranges from 30 degrees south to 20 degrees north, and the greatest concentration of plunges is approximately 12 degrees due south (Figure 11).

Lineations in the metavolcanic rocks are also restricted in their orientation (Figure 12); the major direction of lineation is S.40°W. Plunges are both to the northeast and to the southwest, but plunges to the southwest are more common. The average angle of plunge is approximately 15 degrees. A major difference in lineation trend occurs between the metavolcanic rocks and the gneiss. In the metavolcanic rocks the major trend is to the southwest, whereas in the gneiss it is generally south, a divergence of some 40 degrees. Both units have lineations that are gently plunging.

Joints

Generally at least two joint sets are well developed in the metavolcanic rocks and are closely spaced and steeply inclined, each set being repeated at intervals of 4 or 5 inches. These fractures, coupled with the well-developed foliation and cleavage, allow the rock to readily break into tabular fragments bounded on two sides by foliation planes and on the other four sides by joints. In the gneiss, one well-developed and one poorly defined joint set are generally present in a given exposure; at some places two joint sets may be clearly distinguished. Joints in the gneiss are more widely spaced and are not as conspicuous as those in the metavolcanic rocks. The close, intense jointing of the metavolcanic rocks and the relative lack of close jointing in the gneiss are useful features in distinguishing between small, weathered exposures of the two lithologies.

Two major joint sets in the gneisses and amphibolite are shown in Figure 13. One centers around an attitude of N. 18°E., 75°NW., and the other has a median attitude of N. 88°W., 80°NE. Dips in excess of 70 degrees are most common, although some as gentle as 40 degrees occur. One joint set is normal to the trend of lineations in the gneiss and represents cross joints normal to the fold axes. The other set is nearly parallel to the trend of the fold axes and may be considered as longitudinal; this joint set is more diffuse than the cross joints and appears to be more nearly parallel to the lineations within the metavolcanic rocks than it is to those within the gneiss. The diffuse pattern of this joint set could have resulted from cross joints formed by more than one period of deformation, each forming longitudinal joints that are closely allied in their orientation.

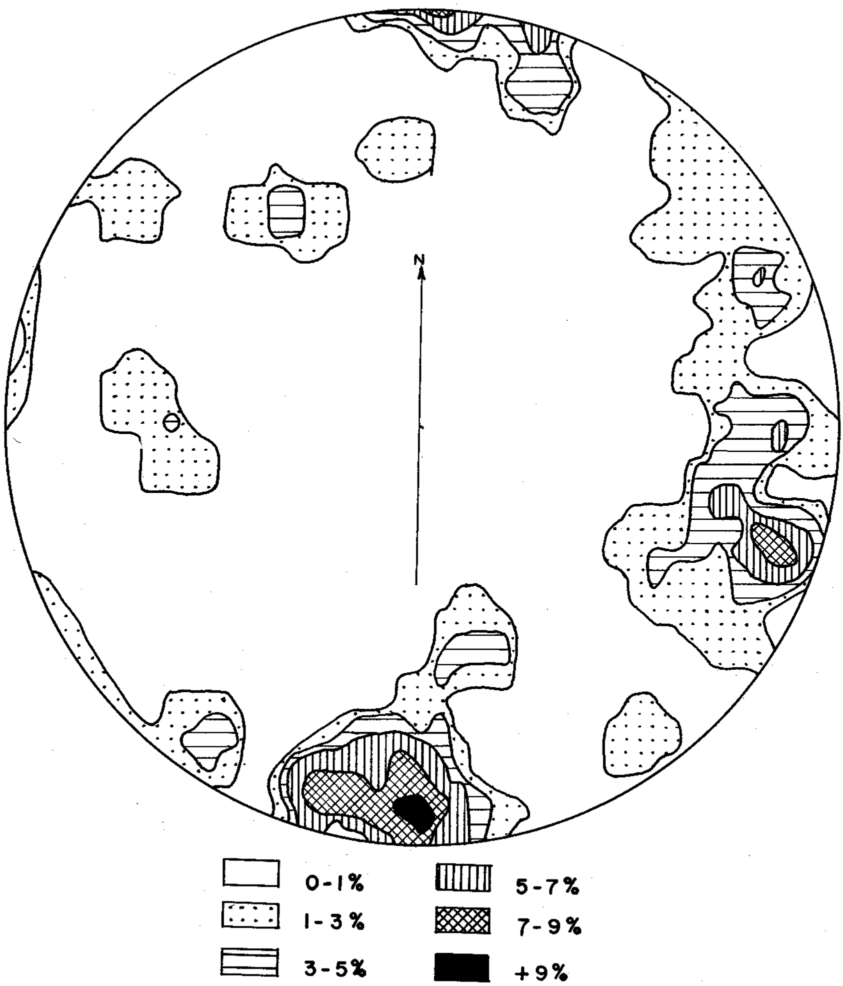


Figure 13. Contour diagram illustrating attitudes of joints in granite gneiss, biotite gneiss, and amphibolite in the Hylas quadrangle. Lower-hemisphere plot based on 53 attitudes.

Joints within the metavolcanic rocks (Figure 14) are extremely diverse, but concentrations of joints center around attitudes of N. 52°W., 70°NE., and N. 16°E., 70°SE. The joint set striking N. 16°E. possibly represents longitudinal joints, whereas those striking N. 52°W. may represent cross joints normal to the fold axes of the metavolcanic rocks.

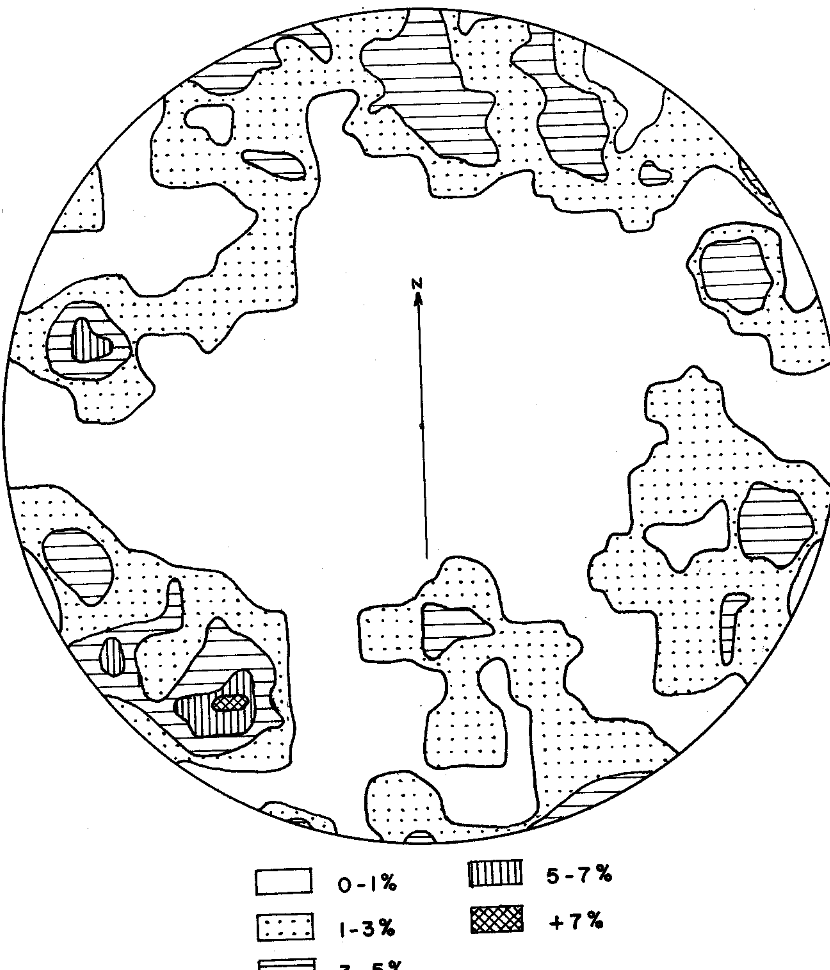


Figure 14. Contour diagram illustrating attitudes of joints in metavolcanic rocks in the Hylas quadrangle. Lower-hemisphere plot based on 70 attitudes.

Both the metavolcanic rocks and the gneisses have longitudinal joints that strike N. 16°E. to N. 18°E., but in the gneiss this joint set primarily dips steeply to the northwest whereas in the metavolcanic rocks it dips steeply to the southeast. Cross joints have different orientations in the two units, but this variation appears to be consistent with the variation in lineations between the gneiss and the metavolcanic rocks. In both cases the cross joints dip steeply to the northeast. The only parallel joint concentration appearing in both units is the relatively weak, but distinct, grouping at an attitude of about N. 22°W., 75°SW. This persistent joint set occurs at an angle of 40 to 45 degrees to the foliation and could be interpreted as an oblique joint set formed by shear. The differences in jointing and the diverse joint sets formed in the two units may have been caused by differing competencies of the two lithologies as they underwent deformation, or due to differing conditions of stress at different times.

Minor Folds

Minor folds, although not common, occur primarily within the metamorphic rocks of the area. One minor fold in biotite gneiss along the tributary to Tuckahoe Creek about 0.3 mile southeast of Goochland Church (Plate 1), just west of the contact with the amphibolite, is typical of the folds in this unit. The fold, about 5 feet across, is a small, plunging, asymmetrical anticline. The eastern limb is inclined at about 40 degrees, and the western limb is inclined at about 70 degrees. The fold has a plunge of 10 degrees to the southeast, and a prominent cross joint cuts the fold normal to its axis. An indistinct cleavage spaced at intervals of about 2 inches cuts the westward-dipping limb of the fold (Plate 1).

Other small folds occur in the amphibolite gneiss on the hill 0.3 mile east of where State Road 676 crosses Shop Creek (Plate 1). There, a series of overturned isoclinal folds occur. The flanks of these folds are inclined at an angle of 19 degrees to the east, parallel to the foliation in the general area and parallel to the axial planes of the folds. The fold axes plunge 5 degrees N. 15°E., parallel to the general trend of lineations in the area.

In outcrop the metavolcanic rocks appear to be largely unfolded, and exposures of this unit are characterized by a pronounced planar foliation. However, in the Royal Stone quarry of Vulcan Materials Company at Hylas the metavolcanic rocks are intensely folded. The folds are asymmetrical to overturned and range in wave length from a few inches to 5 feet. The overturning is to the west, and the folds generally have a gentle plunge to the south. In many, a crude axial plane cleavage, dipping steeply to the east, can be discerned.

MAJOR FEATURES

Richmond Basin

The structure of the Richmond basin of Triassic age has long been a topic of discussion among geologists. As early as 1899, Shaler and Woodworth (p. 445-451) in summarizing the various theories that had been presented concerning the origin and structure of the basin, listed 10 separate concepts. The earliest of these was presented in 1803 by C. F. Volney. Later concepts were presented by Rogers (1836), Lyell (1847), Taylor (1855), Daddow and Bannan (1866), Fontaine (1883), Clifford (1888), Newell (1889), and Russell (1892). Shaler and Woodworth (1899, p. 451), after making extensive studies of the Richmond basin, arrived at conclusions similar to those of Russell and Fontaine. Briefly, these conclusions were that the Triassic sediments were formed in a shallow depression that deepened as filling progressed and ended in faulting and folding caused by lateral compression. They believed that the strata in the Richmond basin represent a downfaulted remnant of a once more extensive series of rocks deposited by lakes or rivers.

Brown (1937) took exception to the concept that the Triassic sediments formerly covered a much more extensive area and believed instead that sedimentation during Triassic time was confined to the present geographic limits of the basins, or nearly so. He thought it was unlikely that the Richmond and Farmville areas could have been connected with the Danville and other areas and be so dissimilar in lithology and fossil content.

The Richmond basin in the area of this report is bounded on the east by a nonconformity and on the west by steeply dipping normal faults. Diagrammatic cross-sections and their locations in the Hylas and Midlothian quadrangles are shown on Figure 15.

Boulder and cobble conglomerates on both margins of the basin indicate that sediments were derived both from the east and the west. Cobbles in the eastern border conglomerate are generally of quartz or granite and are well rounded. Many of the cobbles and boulders in the western border conglomerate are highly angular, have large dimensions, and are composed dominantly of metavolcanic rocks with some granite gneiss. Their large, angular aspect suggests active faulting during Triassic time with little transportation of the boulders, and this in turn indicates

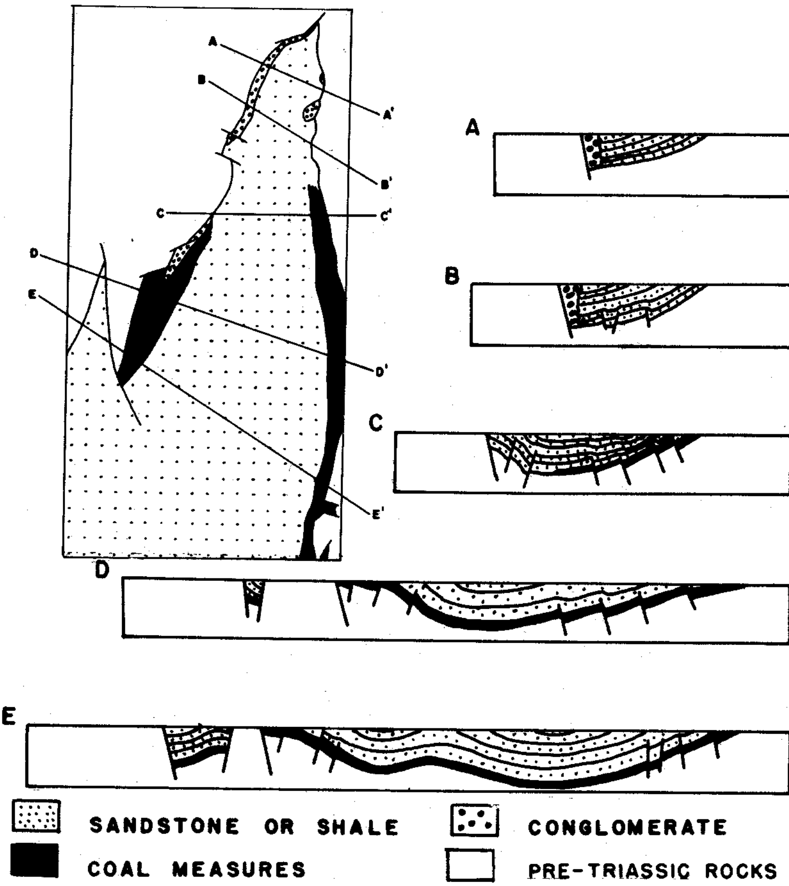


Figure 15. Diagrammatic cross-sections of the Richmond basin and areal sketch map of the Triassic rocks in the Hylas and Midlothian quadrangles.

that the Triassic sediments were deposited in a basin occupying the same geographic locality as that existing today. The basin development was initiated by downward movement on the east side of the major normal fault that bounds much of the Richmond basin to the west. As sediments accumulated, recurring movement along the western fault caused continual deepening of the basin. Although it is possible that Triassic sediments may have extended somewhat beyond the limits of the present basin, it is unlikely that the large boulders in the border conglomerate, especially those near the western border, were transported for any great distance.

The prevalence of westward-dipping beds across the basin may be caused by normal faults that have north-northeasterly trends and steep easterly dips. Although no trace of these faults can be observed at the surface, such faults, and folding caused by adjustment of beds above faults terminating at lower levels, have been reported from old mine workings near the eastern edge of the basin (Shaler and Woodworth, 1899; Roberts, 1928). In much of the western half of the basin, particularly in an area extending for a few miles on either side of the James River (Plate 2), bedding dips to the east.

A profound influence has been exerted locally upon the structure of the Richmond basin by the upthrown block of Petersburg granite which occurs southwest of Manakin (Plate 2) and is bounded on either side by faults that separate it from Triassic sedimentary rocks. The effects of this block, which presumably was upthrown after the completion of the bulk of Triassic sedimentation, are illustrated by the diagrammatic structure sections (Figure 15; Plate 2, Section A-A′).

Movement of this block postdated the major normal border fault and caused it to be offset in the vicinity of the James River. Therefore, the border fault occurs west of the upthrown granite along the western boundary of the Triassic rocks (Figure 15, Sections D-D′, E-E′). In this area the coal measures, which are considered to be present only within the lower 500 feet of the Triassic stratigraphic sequence, occur at depth and are not exposed.

The eastern edge of the upthrown block of Petersburg granite is well exposed in the east end of the Boscobel Granite Corporation quarry west of Manakin (Plate 2). At this locality the fault, which separates Triassic sedimentary rocks on the east from granite on the west, has a north-south strike and a dip of 65 degrees to the east. A mylonite zone about 2 feet thick occurs along the fault, and the adjacent Triassic shale, arkosic sandstone, and thin coal seams are intensely folded. Normal faults of small displacement are conspicuous within the Triassic rocks for over 100 feet away from the fault. The fault exposed at the Boscobel Granite Corporation quarry is believed to have smaller displacement than the border fault, to be later than the border fault, and to be associated with the upfaulting of the granite block. This rising granite mass has caused associated minor normal faults (Figure 15, Sections C-C′, D-D′; Plate 2, Section A-A′) and has brought the coal measures to the surface adjacent to its eastern border. It has also caused the apparent synclinal structure of that portion of the Richmond basin lying east of it.

However, the effects of this uplift are relatively local and diminish both to the north and to the south.

On the eastern margin of the Richmond basin in the vicinity of Blackheath Pond, intersecting normal faults bound a downfaulted block of the coal measures, producing a local eastward extension of Triassic coal that has been extensively mined. A narrow band of Triassic sedimentary rocks which occurs east of the main basin is crossed by U. S. Highway 60 at Falling Creek (Plate 2). These rocks are nonconformable upon the Petersburg granite to the east and are probably bounded by a normal fault to the west.

ECONOMIC GEOLOGY

Crushed stone is presently being produced in both the Hylas (Plate 1) and Midlothian (Plate 2) quadrangles. In the past, coal of Triassic age has been mined in the Richmond basin, but this activity has been dormant for many years. Several prospects for rutile have been made in the northwestern part of the area.

CRUSHED STONE

Three quarries for the production of crushed stone are presently active in the metavolcanic rocks, and one is in the Petersburg granite. The largest quarry in the metavolcanic rocks is the Royal Stone quarry of the Vulcan Materials Company (Plate 1, No. 1), opened in 1958 near Hylas. The upper 30 feet of stone is weathered to a chocolate-brown color; the fresh rock is dark gray-green, fine grained, dense, and highly fractured, and ranges from a phyllite to a medium-grained, poorly banded gneiss.

Crushed stone is also produced from metavolcanic rocks at the Rockville Stone Company quarry (Plate 1, No. 2) about 0.8 mile south of the junction between State Roads 623 and 685, and at the Richmond Crushed Stone Company quarry (Plate 1, No. 3) about 1 mile north of the junction between State Roads 622 and 623. Stone from the Rockville Stone Company quarry is composed primarily of fine-grained, greenish-gray metavolcanic rocks which are highly jointed. These rocks have been intensely folded, and numerous small faults occur in the quarry. The Richmond Crushed Stone Company quarry is near the contact between granite gneiss and metavolcanic rocks, and a gneissic phase of the metavolcanic rocks is being used for crushed stone. The rock is massive and jointing and cleavage are less prominent here than at other places within this unit.

Resources of crushed stone from the metavolcanic rocks are practically unlimited because this unit occurs over a broad area and maintains the same general characteristics throughout. It is comparatively resistant to weathering, and in several localities only minor amounts of overburden would need to be removed in order to allow quarrying of fresh stone. This rock is highly fractured by closely spaced joints, allowing relatively easy removal of the broken rock and facilitating its crushing. Access to good roads allows ready truck transportation for the stone.

Petersburg granite is being quarried by the Boscobel Granite Corporation on the north bank of the James River west of Manakin (Plate 2, No. 4). In this area granite has been injected into metavolcanic rocks along foliation planes, producing alternating layers of igneous and metavolcanic rocks, along with some mixing of the two lithologies. Much of the igneous rock is coarser grained than typical Petersburg granite. Continuous quarrying has been conducted at this site since 1924, and current production is in excess of 200 tons of crushed stone per hour.

The major economic mineral resource in the area of study, therefore, is an abundant supply of crushed stone, and this asset will undoubtedly find an increasing use in future years. As the Richmond area continues to undergo urban expansion, the demand for crushed stone for the vast amount of construction work that accompanies the growth of a major city and its suburbs will continue to increase. Fortunately, this region should be able to provide sufficient crushed stone to satisfy the requirements of future economic growth.

COAL

The mining of coal in the Richmond basin of Triassic age has had a long but fluctuating history, beginning around 1750 (Nicolls, 1904). The Richmond basin is one of the few places in the eastern United States where coals of Triassic age have been mined. Good accounts of coal in the Richmond basin have been given by Ashburner (1888), Shaler and Woodworth (1899), Woodworth (1902), and Roberts (1928); therefore, only a brief summary of the mining history of the area is presented here. From 1701, when coal was first reported in the basin, little production was accomplished until 1795, the first year in which the amount of coal mined exceeded 2000 tons. From 1780 to 1840, most of the coal produced was used locally for domestic purposes, although some was shipped from Richmond to Philadelphia and

New York during the early part of the 19th century. About 2,892,645 tons of coal were produced during this period (Brown and others, 1952, Table 5).

A second flurry of activity occurred from 1842 to 1880. During that time the mines around Midlothian and Gayton were at the peak of their activity, and some of the mines driven at that time were over 800 feet deep. Coal obtained during this active period was used locally and also shipped to industrial centers; it is believed that production during this time was greatly in excess of that which prevailed prior to 1840.

Most of the mines north of the James River around Manakin and Gayton closed down around 1880, and from then until about 1930 production centered around Midlothian and Winterpock south of the James River. The major exception was an incline at Gayton which extended for a total distance of 2400 feet; it was not closed until 1912 (Roberts, 1928, p. 97). Peak production apparently occurred in 1835, with a total production of 201,600 tons (Brown, 1952, Table 5). In 1923, production was about 50,000 tons, and since 1930, production of coal from the Richmond basin has been negligible.

The coal of the Richmond basin is chiefly bituminous and has a dark color and a brilliant luster. An analysis of coal from Carbon Hill, near Gayton (Roberts, 1928, p. 108), was as follows: moisture, 2.81 percent; volatile matter, 25.70 percent; fixed carbon, 62.47 percent; ash, 9.02 percent; and sulfur, 1.43 percent. In many places where the coal has been cut by diabase dikes, natural cokes, similar to those that are produced commercially, have been formed.

Undoubtedly much coal still remains in the Richmond basin, but it is doubtful that this coal is worthy of exploitation at the present time. The coal seams are irregular in thickness and have flexures which have made mining difficult in the past. Although modern mining methods would rectify this to some extent, recovery would still be a difficult process. Even though the proximity of Richmond provides a ready market for coal, adequate sources can be provided elsewhere and transported cheaply in large quantities by rail. In case of emergency the Triassic coals of the Richmond basin could provide a source of energy.

TITANIUM-BEARING MINERALS

Rutile deposits within the area of investigation were described in detail by Watson and Taber (1913, p. 248-261), and were discussed by Brown (1937, p. 34-35). According to these authors the rutile is associated with ilmenite and occurs on the surface of the ground as masses weighing 2 or 3 pounds; a few nodules weigh more than 20 pounds. Rutile also occurs as loose grains on the surface and disseminated in the soil. Watson and Taber (1913, p. 256) stated that in the bedrock rutile generally occurs as dots and streaks in pegmatite dikes cutting the gneiss, and also as very thin streaks or stringers within feldspathic portions of the gneiss itself. The blocks and grains of rutile and ilmenite on the surface were thought to have been derived from weathering of the underlying gneiss and pegmatite, thus freeing the titanium minerals.

Both rutile and ilmenite are sources of titanium, a valuable metal which has been widely used in airplanes, missiles, and space-vehicle components. Titanium dioxide is used in many processes such as the manufacture of high-grade paint, as an opacifier in paper, in welding-rod coatings, and in ceramics. According to Brown (1937), the rutile occurs in an area west and northwest of Centerville, north of U. S. Highway 250. The map presented by Watson and Taber (1913, Figure 20) shows rutile occurring in the area where State Road 621 crosses Tuckahoe Creek. Although prospect pits more than 100 years old have been reported in this area, more intensive prospecting began in 1910. Some of the old prospect pits reached depths of 60 feet, and it has been reported that stringers and lenses of rutile in pegmatite dikes, as well as to a lesser extent in granite gneiss, were present in them. No detailed studies have been conducted on the concentration or abundance of rutile and ilmenite in this area, and a careful evaluation of the region might warrant consideration. The mode of occurrence of rutile within the soil would allow easy mining and separation of the material, and the upper weathered portions of the host rock would also allow relatively easy excavation. Proximity to the expanding industrial center of Richmond would also be in favor of commercial utilization of the rutile and ilmenite in this area.

MONAZITE

Monazite, reported (Mertie, 1953) at two localities, occurs in saprolite formed from weathered metavolcanic rocks. One locality is on the east side of State Road 621 about 0.8 mile north of its intersection with State Highway 6, and the other is on the southwest side of State Highway 6 about 1 mile west of its intersection with State Road 621. Monazite is widely utilized for the production of thorium and the rare-earth elements.

CLAY

The results of tests made on clay obtained from the Triassic coal measures along Gayton Road in the Midlothian quadrangle (Plate 2) were given by Johnson and Tyrrell (1967, p. 87). These tests indicate that the clay has potential use in the manufacture of face brick and structural tile. Other clays derived from the weathering of Triassic shales within the present area of study may be suitable for similar purposes.

GRAVEL

Gravel has been produced from the younger Tertiary gravels at several places in the Midlothian quadrangle (Plate 2), although none of these operations is presently active. The relatively high clay content and excessive amount of ferruginous material in the younger Tertiary gravels make it unlikely that they represent a large potential source of suitable aggregate. The older Tertiary gravels are deeply weathered, highly cemented, and oxidized. Gravel has been produced locally from a thin veneer of colluvial material.

REFERENCES

Ashburner, C. A., 1888, Coal: U. S. Geol. Survey Mineral Resources, 1887, p. 168-382.

Bloomer, R. O., 1938, The geology of the Piedmont in Chesterfield and Henrico counties, Virginia: Unpublished M. S. thesis, Univ. of Virginia.

——— 1939, Notes on the Petersburg granite: Virginia Geol. Survey Bull. 51-F, p. 137-145.

Brown, Andrew, and others, 1952, Coal resources of Virginia: U. S. Geol. Survey Circ. 171, 57 p.

Brown, C. B., 1937, Outline of the geology and mineral resources of Goochland County, Virginia: Virginia Geol. Survey Bull. 48, 68 p.

Clifford, William, 1888, Richmond coal field, Virginia: Manchester Geol. Soc. Trans., vol. XIX, p. 326-353.

Daddow, S. H., and Bannan, Benjamin, 1866, Coal, iron, and oil, or The practical American miner: Pottsville, Pa., 808 p.

Darton, N. H., 1911, Economic geology of Richmond, Virginia and vicinity: U. S. Geol. Survey Bull. 483, 48 p.

Fontaine, W. M., 1883, Contributions to the knowledge of the older Mesozoic flora of Virginia: U. S. Geol. Survey Mon., vol. VI, 144 p.

Johnson, S. S., and Tyrrell, M. E., 1967, Analyses of clay and related materials—eastern counties: Virginia Division of Mineral Resources, Mineral Resources Rept. 8, 232 p.

Lyell, Charles, 1847, On the structure and probable age of the coal field of the James River, near Richmond, Virginia: Geol. Soc. London Quart. Jour., vol. 3, p. 261-280.

Mertie, J. B., Jr., 1953, Monazite deposits of the southeastern Atlantic states: U. S. Geol. Survey Circ. 237, 31 p.

Newell, F. H., 1889, Richmond coal field, Virginia: Geol. Mag., vol. VI, p. 138-140.

Nicolls, W. J., 1904, The story of American coals: Philadelphia, Pa., J. B. Lippincott Co., 405 p.

Roberts, J. K., 1928, The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, 205 p.

Rogers, W. B., 1836, Report on the geological reconnaissance of the State of Virginia: Philadelphia, Pa., 143 p.

Russell, I. C., 1892, Correlation papers—the Newark System: U. S. Geol. Survey Bull. 85, 344 p.

Shaler, N. S., and Woodworth, J. B., 1899, Geology of the Richmond basin, Virginia: U. S. Geol. Survey 19th Ann. Rept., 1897-98, pt. 2, p. 385-515.

Steidtmann, Edward, 1945, Commercial granites and other crystalline rocks of Virginia: Virginia Geol. Survey Bull. 64, 152 p.

Taylor, R. C., 1855, Statistics of coal: 2nd ed., Philadelphia, Pa., p. 287-297.

Volney, C. F., 1803, Tableau du climat et du sol des États-Unis d'Amérique: Paris, 523 p., English translation (1804).

Watson, T. L., 1906, Lithological characters of the Virginia granites: Geol. Soc. America Bull., vol. 17, p. 523-540.

——— 1910, Granites of the southeastern Atlantic States: U. S. Geol. Survey Bull. 426, p. 92-105.

Watson, T. L., and Taber, Stephen, 1913, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3-A, 308 p.

Woodworth, J. B., 1902, The Atlantic Coast Triassic coal field: U. S. Geol. Survey 22nd Ann. Rept. 1900-01, pt. 3, p. 25-53.

APPENDIX I

GEOLOGIC SUMMARY OF DATA FROM TEST BORINGS

Repository number	Elevation at top of hole in feet	Age, depth interval in feet	and description
W-2537	185	Triassic	
		0-24.1	Micaceous, fine- to medium-grained sandstone
W-2538	185	Triassic	
		0-34.4	Micaceous, fine- to coarse-grained sandstone
W-2539	205	Triassic	
		0-34.2	Micaceous, fine- to medium-grained sandstone
W-2540	170	Triassic	
		0-19.4	Micaceous, medium- to coarse-grained sandstone
W-2541	165	Triassic	
		0-14.6	Micaceous, medium- to coarse-grained sandstone
W-2542	135	Triassic	
		0-15.0	Micaceous, brown sandstone
		15.0-19.4	Carbonaceous, fine-grained sandstone
W-2543	158	Triassic	
		0- 5.0	Gray sandstone
		5.0-10.0	Tan shale
		10.0-31.2	Micaceous sandstone
W-2544	165	Triassic	
		0-19.2	Micaceous, fine- to coarse-grained sandstone
W-2545	210	Triassic	
		0-25.0	Brown shale
		25.0-29.4	Micaceous, fine-grained sandstone
W-2546	170	Triassic	
		0-16.0	Micaceous, medium-grained sandstone
W-2547	210	Triassic	
		0-10.0	Silty, fine-grained sandstone
		10.0-18.0	Carbonaceous shale

Repository number	Elevation at top of hole in feet	Age, depth interval in feet, and description	
W-2548	286	Paleozoic	
		0-74.5	Gray, medium-grained granite
		74.5-86.0	Light-gray granite with layers of mica schist
W-2549	231	Tertiary	
		0-22.0	Coarse gravels
		Triassic	
		22.0-49.8	Arenaceous, micaceous shale
W-2550	220	Tertiary	
		0-22.5	Sand
		22.5-28.0	Gravel
		Triassic	
		28.0-39.3	Gray shale
W-2551	215	Tertiary	
		0- 5.0	Gravel
		5.0-15.0	Silt
		15.0-28.0	Gravel
		Triassic	
		28.0-39.5	Dark-gray shale
W-2552	157	Triassic	
		0- 5.0	Silt
		5.0-15.0	Sandstone
		15.0-18.6	Gray, coarse-grained sandstone
W-2553	157	Triassic	
		0-10.0	Clay
		10.0-15.0	Siltstone
		15.0-27.6	Sandstone
		27.6-30.0	Gray shale
W-2554	170	Triassic	
		0-13.0	Clay and gravel
		13.0-15.0	Brownish-gray shale
W-2555	245	Triassic	
		0-15.0	Clay
		15.0-20.0	Siltstone
		20.0-25.0	Brown shale
		25.0-34.4	Siltstone
W-2556	373	Tertiary	
		0-14.0	Clay
		14.0-40.0	Gravel
		Triassic	
		40.0-50.0	Dark-gray shale
		50.0-55.0	Micaceous, coarse-grained sandstone
		55.0-69.5	Dark-gray shale

Repository number	Elevation at top of hole in feet	Age, depth interval in feet, and description	
W-2557	372	Tertiary	
		0-10.0	Clay
		10.0-42.5	Coarse gravel
		Triassic	
		42.5-45.0	Clay
		45.0-49.5	Micaceous, fine-grained sandstone
W-2558	211	Tertiary	
		0-10.0	Clay
		10.0-18.0	Gravel
		Triassic	
		18.0-20.0	Clay
		20.0-25.0	Coal
		25.0-30.0	Dark-gray to brownish-gray shale
W-2559	156	Tertiary	
		0-10.0	Reddish clay
		10.0-23.0	Coarse gravel
		Triassic	
		23.0-24.5	Coal
W-2560	215	Tertiary	
		0-30.0	Silt and clay
		Triassic	
		30.0-45.0	Micaceous, slightly carbonaceous siltstone
		45.0-60.0	Sandstone and siltstone
		60.0-69.5	Brownish-black sandstone
W-2561	208	Tertiary	
		0-35.0	Clay and silt
		Paleozoic	
		35.0-95.0	Tan, brown, and gray granite
W-2562	188	Tertiary	
		0-20.0	Pebbly clay and sand
		Triassic	
		20.0-30.0	Micaceous, fine-grained sandstone
		30.0-35.0	Yellowish-brown shale
		35.0-40.0	Coal
W-2563	225	Tertiary	
		0-12.0	Clay
		Triassic	
		12.0-15.0	Brown and tan shale
		15.0-20.0	Brown, micaceous sandstone
		20.0-25.0	Micaceous, sandy siltstone
		25.0-30.0	Micaceous, dark-gray sandstone

Repository number	Elevation at top of hole in feet	Age, depth interval in feet, and description	
W-2564	223	Tertiary	
		0-14.0	Gravel
		Triassic	
		14.0-25.0	Gray shale with minor sandstone
W-2565	214	Triassic	
		0-15.0	Micaceous, carbonaceous clay
		15.0-20.0	Brown, micaceous siltstone
		20.0-29.5	Brownish-red shale
W-2566	399	Tertiary	
		0-30.0	Coarse gravel
		30.0-35.0	Silt and clay
		Triassic	
		35.0-65.0	Brown to gray, micaceous sandstone
		65.0-73.0	Red shale
W-2567	365	Tertiary	
		0-10.0	Red clay
		10.0-23.0	Coarse gravel
		Triassic	
		23.0-45.0	Brown and gray shale
		45.0-52.0	Gray, micaceous sandstone
W-2568	358	Tertiary	
		0-22.0	Gravel
		Triassic	
		22.0-53.5	Brown and gray shale
W-2569	211	Tertiary	
		0-20.0	Clay and coarse gravel
		Triassic	
		20.0-25.0	Brown sandstone
		25.0-30.0	Coal
		30.0-34.8	Black, carbonaceous shale
W-2570	252	Tertiary	
		0-22.0	Gravel
		Triassic	
		22.0-25.0	Tan shale
		25.0-35.0	Brown siltstone
		35.0-44.5	Brownish-gray shale
W-2571	285	Tertiary	
		0- 5.0	Sand and gravel
		Triassic	
		5.0-20.0	Clay and shale
		20.0-25.0	Micaceous, fine-grained sandstone
		25.0-33.2	Brownish-gray, carbonaceous shale

APPENDIX II

APPROXIMATE MINERAL COMPOSITION OF ROCKS IN THE HYLAS AND MIDLOTHIAN QUADRANGLES

Locations of Repository Numbers (Plate 1).

Granite gneiss: R-3088, along Tuckahoe Creek, 0.3 mile downstream from bridge of State Road 621 and 0.5 mile NNE of Centerville, Goochland Co.; R-3090, along Tuckahoe Creek, 1.2 miles WNW from bridge of State Road 621 over the creek, Goochland Co.; R-3091, intersection of tributary of Dover Creek and trail, 0.95 mile north of the north end of Dover Lake, Goochland Co. Garnetiferous biotite gneiss: R-3087, SE side of South Anna River, 0.05 mile SW of bridge of State Road 673 over the river, Hanover Co.; Biotite granite gneiss: R-3089, along intermittent stream, 0.2 mile north of Goochland Church and just east of State Road 621, Goochland Co.

Amphibolite: R-3092, on hill, 0.3 mile east of bridge of State Road 676 over Shop Creek and 0.7 mile north of Rockville School, Hanover Co.; R-3093, along intermittent stream, 0.1 mile SE of South Anna River and 2.6 miles north of Hylas, Hanover Co.; R-3094, between Tuckahoe Creek and State Road 621, 0.65 mile NW of Centerville, Goochland Co.

Metavolcanic Rocks: R-3095, 0.05 mile NW of St. Matthews Church, Goochland Co.; R-3096, along Anderson Creek just south of State Road 623, Goochland Co.; R-3097, along Little Tuckahoe Creek, 0.2 mile upstream from bridge of State Road 623, Goochland Co.

Granite Gneiss and Biotite Gneiss (in percent).

	R-3087	R-3088	R-3089	R-3090	R-3091
Quartz	27.6	45.5	31.3	52.5	36.1
Potassic feldspar	3.1	30.5	26.3	32.5	36.9
Plagioclase feldspar	19.1	9.6	13.6	11.7	13.7
Biotite	31.9	.2	18.9	2.6	6.6
Amphibole	4.8	7.2	.6	—	6.1
Garnet	12.4	5.0	4.3	.3	—
Calcite	—	—	—	—	.3
Black opaque	.6	.3	.2	—	.1
Accessories	.5	.4	4.7	.4	.2

Amphibolite (in percent).

	R-3092	R-3093	R-3094
Quartz	5.4	9.4	16.7
Potassic feldspar	4.6	13.8	5.8
Plagioclase feldspar	12.2	22.0	23.7
Amphibole	40.8	53.6	52.5
Pyroxene	32.5	—	—
Calcite	1.8	—	—
Black opaque	—	—	.4
Accessories	2.7	1.2	.9

Metavolcanic Rocks (in percent).

	R-3095	R-3096	R-3097
Quartz	23.5	32.5	40.9
Potassic feldspar	37.9	44.3	43.0
Plagioclase feldspar	7.8	5.7	7.0
Biotite	23.5	—	—
Muscovite	3.7	16.6	—
Chlorite	.9	5.3	—
Amphibole	—	—	3.2
Black opaque	2.4	.6	.6
Accessories	.3	.3	—

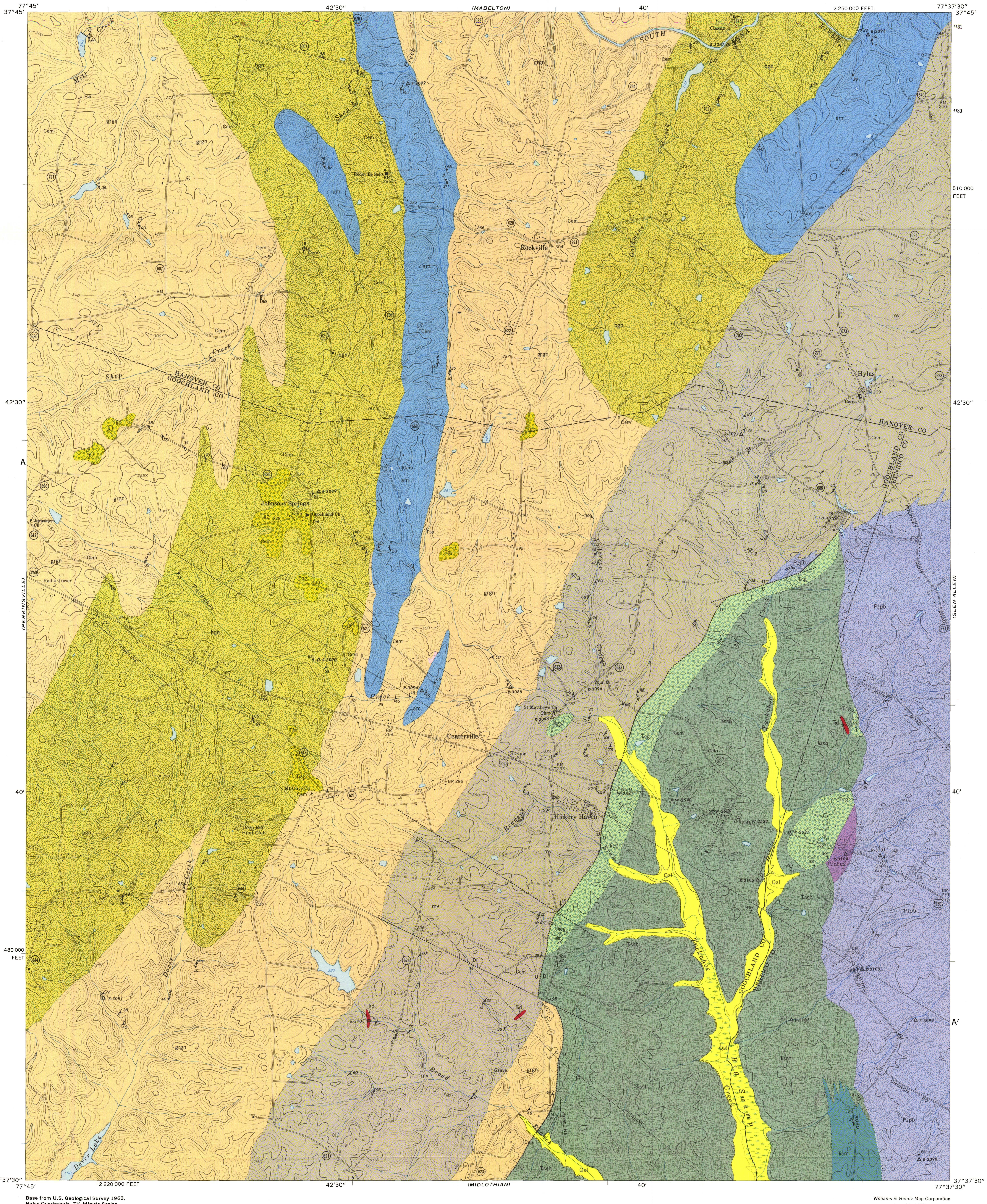
INDEX

PAGE

PAGE

PAGE

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



Base from U.S. Geological Survey 1963, Hylas Quadrangle, 7½-Minute Series

Williams & Heintz Map Corporation

GEOLOGIC MAP OF THE HYLAS QUADRANGLE, VIRGINIA

Geology by Bruce K. Goodwin

Magnetic North 6° True North
1963 MAGNETIC DECLINATION

SCALE 1:24 000
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER
CONTOUR INTERVAL 10 FEET

1970

VIRGINIA
QUADRANGLE LOCATION

EXPLANATION

CENOZOIC

QUATERNARY

Qal — Alluvium

TERTIARY

Tg2 — Gravels
Tg2, *gravel, sand, and clay.*

MESOZOIC — TRIASSIC

Ꞧd — Diabase dike

Ꞧcg, Ꞧssh, Ꞧcm — Newark Group
Ꞧcg, *conglomerate;* Ꞧssh, *sandstone and shale;* Ꞧcm, *coal measures.*

PALEOZOIC

Pzpb, Pzpbm — Petersburg granite
Pzpb, *granite;* Pzpbm, *quartz monzonite porphyry.*

PRECAMBRIAN(?)

mv — Metavolcanic rocks

am — Amphibolite

bgn — Biotite gneiss

grgn — Granite gneiss

CONTACTS

exposed
approximate
covered

FAULTS

exposed
approximate
U — upthrown side
D — downthrown side

ATTITUDE OF ROCKS

75 Strike and dip of beds
55 Strike and dip of foliation
75 Strike and dip of joints
18 Bearing and plunge of lineation

QUARRIES AND PROSPECTS

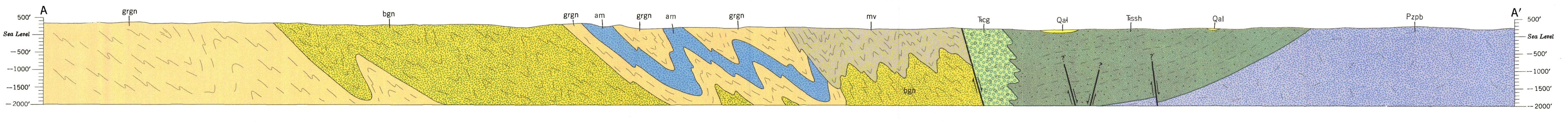
1 Active
1. Vulcan Materials Company
2. Rockville Stone Company
3. Richmond Crushed Stone Co.

SAMPLE LOCATIONS

R-3087 Representative samples of lithologies mapped

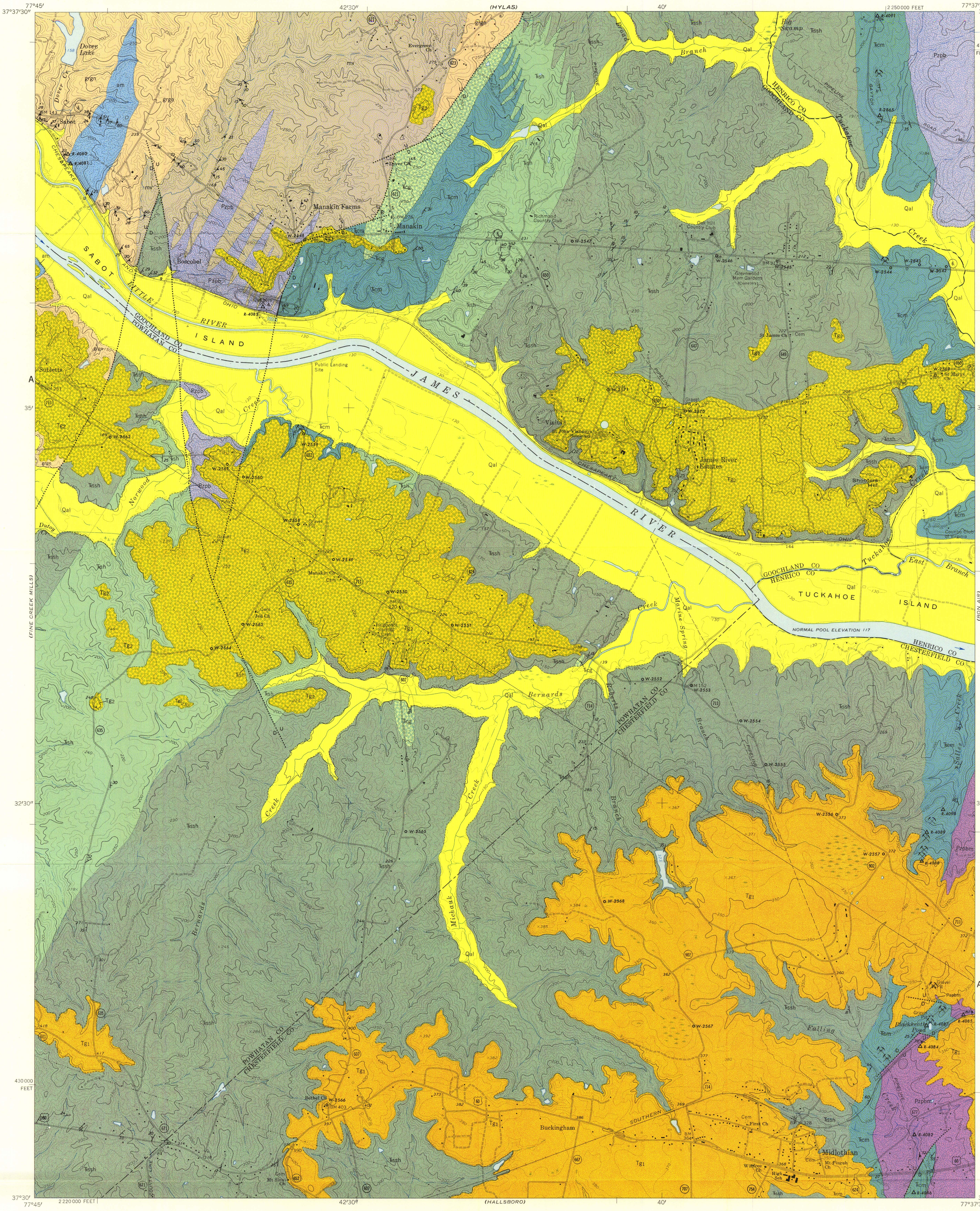
STRATIGRAPHIC CONTROL

W-2540 Location of test boring



Interpretive cross section
with no vertical exaggeration

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



EXPLANATION

CENOZOIC

QUATERNARY

Qal
Alluvium

TERTIARY

Tg2
Tg1
Gravels
Tg2, *gravel, sand, and clay.* Tg1, *gravel, sand, and clay; highly weathered and partially cemented*

MESOZOIC

TRIASSIC

Ʀcg Ʀssh Ʀsh Ʀcm
Newark Group
Ʀcg, *conglomerate;* Ʀssh, *sandstone and shale;* Ʀsh, *shale;* Ʀcm, *coal measures.*

PALEOZOIC

Pzpb
Pzpbm
Petersburg granite
Pzpb, *granite;* Pzpbm, *quartz monzonite porphyry.*

PRECAMBRIAN(?)

mv
Metavolcanic rocks

am
Amphibolite

grgn
Granite gneiss

CONTACTS

exposed
approximate
covered

FAULTS

exposed
approximate
U — upthrown side
D — downthrown side

ATTITUDES OF ROCKS

75 Strike and dip of beds
55 Strike and dip of foliation
75 Strike and dip of joints
18 Bearing and plunge of lineation

QUARRIES AND PROSPECTS

4 Active
4. Boscobel Granite Corp.
Abandoned coal mines
Abandoned coal prospects

SAMPLE LOCATIONS

R-2865 Representative samples of lithologies mapped or raw materials that have potential use in the ceramic industry

STRATIGRAPHIC CONTROL

W-2550 Location of test boring

Base from U. S. Geological Survey 1964, Midlothian Quadrangle, 7½-Minute Series

GEOLOGIC MAP OF THE MIDLOTHIAN QUADRANGLE, VIRGINIA

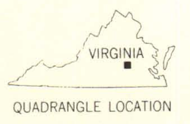
Geology by Bruce K. Goodwin

Williams & Heintz Map Corporation

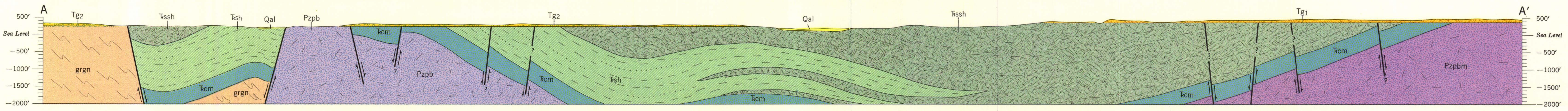
6°
True North
Magnetic North
1964 MAGNETIC DECLINATION

SCALE 1:24 000
1 MILE
7000 FEET
1 KILOMETER
CONTOUR INTERVAL 10 FEET

1970



QUADRANGLE LOCATION



Interpretive cross section with no vertical exaggeration

ERRATA ON GEOLOGIC MAPS

Plate 2. Under sample locations, the triangle for R-2865 should be solid; all other open triangles are representative samples of lithologies only.